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DO UNIT LABOR COST DRIVE INFLATION IN THE EURO AREA?

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Do Unit Labor Cost Drive Inflation in the Euro Area?

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Abstract

The purpose of this study is to analyze the relationship between unit labor costs and inflation. We estimate an optimal price path model based on a New Keynesian Phillips Curve for eleven euro area countries individually, under the assumption that unit labor costs are proportional to marginal costs. We seek such a model which minimizes the distance between fitted and actual price level fluctuations, with parameters that satisfy theoretical restrictions. The econometric methodology used is a two-step approach method.

Estimates show that in eight of the eleven euro area countries there is a plausible relationship between unit labor costs and price level dynamics. The average time needed to adjust prices in line with movements in unit labor costs is estimated to be around eight months. In the case of Slovakia the results indicate rather flexible prices.

JEL classification: C22, E12, E3, J3
Key words: inflation, unit labor costs, NKPC, Euro area, VAR

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1 INTRODUCTION

Understanding the nature and sources of inflation in the euro area is important for more efficient preservation of price stability by the European Central Bank. The ability to define the drivers of price level fluctuation enables deeper understanding of private sector expectations formation and easier determination of the role of nominal price rigidities in an economy.

The existence of sticky prices makes monetary policy able to affect real economic activity by influencing the nominal interest rate, at least in the short run. Nominal price rigidities are at the foundations of the New Keynesian theory following from the assumption of imperfect competition among firms. In such an economic environment monopolistic firms are price setters that want to maximize their future profits and set their prices above marginal costs. Therefore what one really whishes to stabilize, in order to minimize the deadweight losses, is the time depended markup of price level over marginal costs.

The assumption of proportionality of marginal costs to unit labor costs (ULC) was used in various studies due to the fact that ULC includes wage rigidities.[2] Christoffel, Kuester and Linzert (2009) in their paper about the role of labor markets for euro area monetary policy claimed that a lower degree of wage rigidity makes monetary policy more effective, i.e. a monetary policy shock transmits faster into inflation. Rigid wages were defined as the main source of sluggish cyclical movement in marginal costs in the U.S. and also in the euro area. Finally, some authors like Sbordone or Galí, Gertler and López-Salido discovered that to explain the majority of fluctuations in the price level it is sufficient to assume the marginal cost are proportional to ULC and fluctuations in the markup.

The purpose of this study is to analyze the relationship between unit labor costs and inflation. We estimate an optimal price path model individually for every euro area country observed; under methodology used by Sbordone (2002, 2005). Such a model was not yet estimated on euro area data. Under Sbordone's method we test implications that depend only on the firm's optimal pricing problem and therefore we can more easily understand the effect of each assumption on the results. We take as given the evolution of a number of state variables and determine what path of prices is predicted by the evolution of the exogenous variables. The advantage is that our results do not depend on arbitrary identification procedure to extract structural shocks from the residuals of an estimated time series model. By using this methodology we seek a model that minimizes the distance between fitted and actual price level fluctuations with parameters which satisfy the theoretical restrictions. In the economic environment of forward looking monopolistic firms, covered by our model, agents believe that dynamics of unit labor costs, proportional to movements in marginal costs, are exogenous and Granger cause inflation. Various inflation indicators will be tested, including also the core inflation where we expect the most significant results, since it excludes certain items that face volatile price movements like food products and energy. The fit of the model with nominal price rigidities (New Keynesian Phillips Curve) will be compared with a flexible price model based on real business cycle

[2] The assumption of the proportionality of marginal costs to unit labor costs can be justified by the use of a Cobb-Douglas production function; further explanation in Galí, Gertler and López-Salido (2001) or Sbordone (1999, 2002).

theory, where we assume perfectly competitive output and input markets and prices that adjust every period to the movements in unit labor costs.

It should be also noted that the sensitivity of inflation to unit labor costs varies systematically across economic sectors, e.g. the service sector tends to have stickier prices than the manufacturing sector. In view of this fact we expect that the causality of fluctuations in ULC differs across sectors and implies diverse significance levels of impacts on inflation dynamics. For every euro area country observed we search for a specific economic sector which validates that unit labor cost dynamics drive inflation and these sectoral data will be used to estimate the theoretical inflation.

We will show that productivity, wages and inflation move largely together as the New Keynesian theory suggests. In accordance with our expectations about inflation indicators the use of core inflation in the New Keynesian Phillips Curve (NKPC) is the most significant. In line with this fact in eight of eleven euro area countries observed there is a plausible relationship between unit labor costs and the price level. Our estimation results show that the average time needed to adjust prices to movements in unit labor costs is around eight months. Slovakia is specific in the sense of putting more weight on the flexible price model. This estimation result coincides also with analyses of Gertler and Senaj (2008) on downward wage rigidities in Slovakia based on micro foundation, where they concluded rather flexible nominal compensations.

The paper is organized as follows. In the sections 2 and 3 we will present some theoretical background to the topic analyzed, and describe the models with flexible and sticky prices in more detail. The empirical part in section 4 will cover the data used and the estimation procedure on the basis of a two-step approach method where the forecasting VAR is estimated separately from the pricing parameters. Finally, the last two sections comprise results and some concluding remarks.

2 LITERATURE OVERVIEW

The New Keynesian models are typically static, designed mainly for qualitative analyses. The indicators added to the flexible real business cycle model, which form the New Keynesian model branches, are monopolistic competition and nominal rigidities.

In line with Calvo (1983) price rigidities follow from monopolistic competition among firms that have their own rules for changing their price levels. The monopolistic firms are forward looking, set markup price over their marginal costs ($P>MC$), and base their pricing decision on the expected future behavior of marginal costs. Such an economic environment is covered by the New Keynesian Phillips Curve, where the log-linearization of optimality conditions around zero inflation steady state relates inflation to expected future inflation and real marginal costs. According to Galí and Gertler (1999) NKPC is of the form:[3]

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[3] In the empirical implementation of Galí and Gertler (1999), they use measures of real marginal cost in place of an ad hoc output gap, as theory suggest. A desirable feature of a marginal cost measure is that it directly accounts for the impact of productivity gains on inflation, a factor that simple output gap measures often miss. When the output gap is used, we get the pricing equation $\pi_t = \beta E_t \pi_{t+1} + \kappa \hat{y}_t$, where $\kappa = \varphi\delta$ and δ measures output elasticity of real marginal costs. For more details on how to derive the equations see Woodford (2003,ch.3).

$$\pi_t = \beta E_t \pi_{t+1} + \varphi \, rmc_t + const \,, \quad (1)$$

where rmc_t represents the logarithm of average real marginal costs in the economy, β is a discount factor, *const* is a constant term[4] that is equal to $\varphi \ln(\in/(\in -1))$, where $\in$ represents the elasticity of demand.[5]

In this economic environment there are two types of firms. Let θ represent a fraction of firms which do not reset prices optimally at time *t*, in other words it is an indicator of nominal rigidities. The frequency of optimal price adjustments is then defined by a fraction *(1-θ)* of firms, which can adjust their prices each period, independently of ex ante price dynamics, and the time that is needed to adjust the price is *1/(1-θ)*. The parameter φ from the NKPC equation is the "inertia" coefficient which is in the simplest form a nonlinear function of structural parameters: $\varphi = (1-\theta)(1-\beta\theta)/\theta$. It follows that the lower the frequency of price adjustment, the fewer firms adjust prices in any period, and hence the less sensitive inflation will be to marginal costs and the smaller is φ. A smaller φ also implies that marginal costs are less sensitive to output and price adjustment will be less sensitive[6] to movements in output.

As already mentioned, in this monopolistic environment firms set their prices as a markup over current and expected marginal costs. Under flexible prices firms set their prices each time period due to a constant markup over nominal marginal costs. According to Rotemberg (1982) an introduction of nominal rigidities determined by price adjustment costs the markup of a firm starts to fluctuate. This means that instead of a constant relation between price and nominal marginal costs, there exists a time period dependent markup. To sum up, prices are sticky because firms face subjective cost of changing their prices.

Recent empirical implementations stress the idea that the Calvo-style models link inflation to the behavior of labor share of income (real unit labor costs) used as a proxy of real marginal costs. Galí and Gertler (1999), Galí, Gertler and López-Salido (2001,2005), Kurmann (2005), Rabanal and Rubio-Ramiréz (2005), Woodford (2001) and Sbordone (2002,2005) find evidence that the New Keynesian Phillips Curve gives reasonable approximation of US inflation dynamics when labor share of income is used. Galí, Gertler and López-Salido (2001) and Paloviita (2004) get the same conclusion for euro area inflation dynamics. Following

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[4] Actually the constant term can be ignored because we want to compute inflation deviations from the mean, therefore in our calculation this term does not appear anymore. It should be also noted that $\in/(\in -1)$ is the equilibrium markup μ*, derived from the first order condition for the optimal choice of price level evaluated at a symmetric equilibrium based on price adjustment cost a firm is facing.

[5] Elasticity of demand should be greater than one due to the resulting bigger percentage change in demand than in price. This implies a profit maximization behavior of a firm which sets prices greater than marginal cost. But in the case when the elasticity of demand goes to infinity individual products become closer substitutes and the individual monopolistic firm has less economic power due to perfect competition. Then prices are set to be equal marginal costs and we get a constant markup over time equal to one.

[6] Potentially relevant are pricing complementarities that may induce firms to minimize the variation in their relative prices. These pricing complementarities, known in the literature as real rigidities, induce firms that are adjusting prices to want to keep their relative price close to the non-adjusters. The net effect of real rigidities is to reduce φ and thus reduce the overall sensitivity of inflation to output. (Woodford, 2003).

their results it means that central banks should raise interest rates in response to increases in labor share of income.

However, Tillman (2005) presented in his paper that the explanatory power of the staggered price setting scheme for euro area inflation is limited due to a large degree of estimation uncertainty and they cannot say whether the Calvo model for euro area data actually fits or fails. They also discovered that the inclusion of backward looking component into the NKPC narrows confidence bands, but still cannot generate sufficiently precise estimates. Also the results of the approach of Paloviita (2004) indicate there is more weight on backward looking indexation. On the contrary, Galí, Gertler and López-Salido (2001) demonstrated with their results that the forward looking NKPC fits the euro area data very well, possibly better than the U.S. data.[7]

In our paper we focus on the methodology of Sbordone (2002, 2005) in its restricted form that assumes only forward looking behavior of firms, where agents believe that dynamics of marginal costs are exogenous and Granger cause inflation. She combines the methodology of Rotemberg with Calvo, what allows one to interpret the estimate of the cost of adjusting price of the Rotemberg model as nominal rigidities examined in terms of the average expected time between price changes in the Calvo model.

3 Review of Theory behind the Models with Flexible and Staggered Pricing

In our approach we test implications that depend mainly on the firm's optimal pricing problem in line with Sbordone (2002, 2005). She discovers that models of imperfect competition with nominal rigidities deliver an extremely close approximation to the dynamics of the inflation process, even using a very simple measure of marginal costs, which are assumed to be proportional to unit labor costs.

3.1 Model with Flexible Prices

At first we derive the model with flexible prices, therefore we assume perfectly competitive output and input markets. We assume that each firm produces a single good *Y* and wants to maximize its profits, under Cobb-Douglas production function: $Y_t = Z_t(H_t)^{1-\alpha}$, where H_t and Z_t represent labor inputs and aggregate labor-augmenting technological progress, where $(1-\alpha)$ is the share of labor in the production function and $0\leq\alpha<1$. The nominal marginal costs are derived by taking the first order derivative of the firm's cost function and are in the end proportional to unit labor costs, $MC_t=(1/1-\alpha)(ULC_t)$. Unit labor costs are in our case equal to

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[7] The assumption of forward looking behavior of the monopolistic firms was supported for the U.S. data by Sbordone (2005), Galí and Gertler (1999), Galí, Gertler and López-Salido (2005) and for the UK data by Batini, Jackson and Nickell (2005). The use of backward looking indexation was dominant in papers of Rudd and Whelan (2005) and Linde (2005), working with U.S. data. Kurmann (2005), who worked with methods of Galí and Gertler and Sbordone, discovered that we cannot definitely say if putting more weight on forward or backward looking behavior is the right decision, due to the resulting great amount of uncertainty about the fit of theoretical inflation with data.

$(Ht,W_t)/Y$, where H_t stands for hours worked and W_t is nominal compensations paid. In a model with flexible prices the optimal price should be equal to marginal costs ($P=MC$) with a constant markup, $\mu=1$. The equilibrium is then defined by

$$\pi_t = \Delta ulc_t , \tag{2}$$

representing the equality between log deviations of respective growth rates from the mean. The prices adjust in relation to the changes in unit labor costs, which are assumed to be exogenous and independent of movements in price levels, and this will determine our benchmark model.

3.2 MODEL WITH NOMINAL RIGIDITIES

In this setting we have a continuum of monopolistic firms, which produce differentiated goods and want to maximize their future profits. By maintaining the Cobb-Douglas technology the marginal costs can be still measured by unit labor costs. The introduction of nominal rigidities determined by price adjustment costs leads to fluctuations in markup. So instead of a constant relation between price and nominal marginal costs, as we had before, there exists a time period dependent markup μ_t, $MC_t = (\mu_t /1\text{-}\alpha)(ULC_t)$. We expect convex price adjustment costs where the minimum is determined by constant inflation ($\ln(p_t / p_{t-1}) = 0$). After log-linearization due to Sbordone (2002, 2005) we get equilibrium pricing condition where the price level is determined by past price levels, unit labor costs, and the weighted sum of expected unit labor costs:

$$p_t = \lambda_1 p_{t-1} + (1-\lambda_1)ulc_t + (1-\lambda_1)\sum_{j=0}^{\infty}\lambda_2^{-j}E_t\Delta ulc_{t+j} \tag{3}$$

where all variables are expressed as log deviations from the mean.[8] After rewriting the whole equation into a stationary model we get:

$$\pi_t = \lambda_1\pi_{t-1} + (1-\lambda_1)\Delta ulc_t + (1-\lambda_1)\left(\sum_{j=0}^{\infty}\lambda_2^{-j}E_t\Delta ulc_{t+j} - \sum_{j=0}^{\infty}\lambda_2^{-j}E_{t-1}\Delta ulc_{t+j-1}\right) \tag{4}$$

λ_1 and λ_2 in both equations (3) and (4) are the two roots of the polynomial $P(\lambda)$: $P(\lambda) = \beta\lambda^2 - (1+\beta+\varphi)\lambda + 1 = 0$,where $\lambda_1 = \theta,\ \lambda_2 = 1/\beta\theta$ and the parameters should follow these restrictions $0<\beta<1$ and $0<\theta<1$. Under these conditions equation 4 can be rewritten to:

$$\pi_t = \theta\pi_{t-1} + (1-\theta)\Delta ulc_t + (1-\theta)\left(\sum_{j=0}^{\infty}(\beta\theta)^j E_t\Delta ulc_{t+j} - \sum_{j=0}^{\infty}(\beta\theta)^j E_{t-1}\Delta ulc_{t+j-1}\right) \tag{5}$$

Profits are discounted using a stochastic discount factor β, $0<\beta<1$. For the firm to have the discount factor less than one simply means that it places less weight on future losses than on today's losses.[9] The parameter β should also coincide with utility discount factor of the

[8] The derivation of equation 3 from equation 1 is shown in the appendix.
[9] One euro today is worth more than one euro tomorrow because it can be reinvested. By the same argument, one euro lost today is more important than a one euro lost tomorrow.

representative household.[10] This means that when $\beta<1$ the representative household prefers to consume today rather than tomorrow due to a higher utility of present consumption. It is also an important assumption for the analysis of optimal policy, e.g. if $\beta=1$ the household is indifferent between consumption today and tomorrow.

Because we want to assume that more weight is placed on future marginal costs the value of β should be close to 1. Besides this assumption there exists also another reason for a discount factor near one: for the sake of β to be included in the determination of the steady state real interest rate where r_t equals $(\beta^{1}\text{-}1)$. Therefore it is more relevant to set β close to one to get a plausible annual interest rate, e.g. $\beta=0.99$ with $r=4\%$ or $\beta=0.98$ with $r=8\%$. In our case we decided to calibrate the discount factor β first to the value of 0.99 in line with Sbordone (2005), Woodford (2001), Rudd and Whelan (2002), Rabanal and Rubio-Ramírez (2005) and Lawless and Whelan (2007), and later on to $\beta=0.98$ to test the robustness of our results.

In the case of flexible prices, where the fraction of firms which set prices each period independently of the past price behavior $(1-\theta)$ is equal 1, equation 5 simplifies to equation 2. On the other hand the higher the price adjustment costs, the closer the fraction of firms which do not adjust prices optimally (θ) to 1. In such a case the firms put more weight on past inflation dynamics and expectations play a negligible role.

However, we have actually two possibilities how to derive the "inertia" coefficient φ:

a) In the limiting case of a linear technology where we expect constant returns to scale what leads to ($1\text{-}\alpha$) equal to 1, all firms will be facing common marginal costs and the coefficient simplifies to the known equation of structural parameters:

$$\varphi = \frac{(1-\theta)(1-\beta\theta)}{\theta}. \tag{6}$$

b) Now by assuming increasing marginal costs that vary across firms where $0<\alpha<1$ we get the following relationship for the "inertia" coefficient:

$$\varphi = \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{(1-\alpha)}{1-\alpha(1-\epsilon)}. \tag{7}$$

The coefficient is decreasing in the curvature of the production function determined by α and in the elasticity of demand, ϵ. The larger are α and ϵ, the more sensitive are the marginal costs of an individual firm to deviations of its price from the average price level (everything else equal). This means that a smaller adjustment in price is required to compensate expected movements in average marginal costs. (Galí, Gertler and López-Salido; 2001)

The assumption of varying marginal costs produced more plausible estimates of the degree of price rigidity (θ) in compared to the case with no wedge between firm's and the average marginal costs (see Tab. 1). In this paper we analyze the impact of the use of constant returns to scale as well as of decreasing returns to scale on the value of nominal price rigidities θ in the model.

[10] Sbordone (1998, 2002) and Kurmann (2005) set β for example equal 1. In a point stressed in Woodford (2003) this amplification may seem appealing, in that it implies a vertical „long-run" inflation-output trade off, but correctly accounting for the presence of the utility discount factor of the representative household has important consequences for the analysis of optimal policy.

Table 1 Various Results of the Degree of Price Stickiness (θ) with Different Parameters (α, ϵ, μ) Used

	α	ϵ	μ	case	θ	1/(1-θ) in quarters
US:						
Sbordone (2002)	0.25	6	1.20	(b)	0.66	2.9
				(a)	0.79	4.8
Galí, Gertler, López-Salido (2001)	0.27	11	1.10	(b)	0.43	1.8
				(a)	0.70	3.3
Kurmann (2005)	0.40	10	1.11	(b)	0.60	2.5
				(a)	0.83	5.9
Rudd and Whelan (2002)				(a)	0.77	4.4
Rabanal and Ramiréz (2005)				(a)	0.67	3.0
Euro Area:						
Galí, Gertler, López-Salido (2001)*	0.175	11	1.10	(b)	0.70	3.3
				(a)	0.83	5.9
Lawless and Whelan (2007)	0.175	11	1.10	(b)	0.59	2.4
				(a)	0.75	4.0
Paloviita (2004)				(a)	0.77	4.3

Explanatory note: (a) constant returns to scale, (b) decreasing returns to scale.
**They derived the parameters from the following definition: ($1-\alpha$) equals the average labor income share of the euro area (3/4) times the chosen markup (μ).*

4 Econometric Method and Data

Different econometric methods were used to correctly estimate inflation dynamics, such as: maximum likelihood (Rotemberg, 1983; Linde, 2005), two-step approach method (Sbordone, 2002, 2005; Kurmann, 2005; Tillman, 2005), Bayesian approach (Rabanal and Rubio-Ramírez, 2005) and the widely used general method of moments (Galí and Gertler, 1999; Galí, Gertler and López-Salido, 2001, 2005; Rudd and Whelan, 2005; Batini, Jackson and Nickel, 2005; Paloviita, 2004).

In our paper we focus on the methodology of Sbordone in its restricted form that assumes only forward looking behavior of firms, where agents believe that dynamics of unit labor costs are exogenous and Granger cause inflation. We will test the Granger causality. In computing the theoretical inflation we use the minimum distance method based on a two-step approach, where the forecasting VAR is estimated separately from the pricing parameters β and φ .

We take as given the paths of unit labor costs and output, and determine the path of prices predicted by the sticky price model (eq. 5). We choose four indicators of inflation: CPI (consumer price index), core CPI (excluding food and energy), HICP (harmonized CPI) and GDP deflator. We work with data[11] for 11 euro area countries (Austria (AT), Belgium (BE), Spain (ES), Finland (FI), France (FR), Germany (DE), Ireland (IE), Luxembourg (LU), Netherlands (NL), Portugal (PT) and Slovakia (SK)) and for comparison also with U.S. data covering the time period 1989Q2-2008Q2.

GDP deflator is a standard price level index used in new Keynesian macroeconomic studies. We tested the assumption that GDP deflator dynamics Granger causes inflation and examined insignificancy in the case of U.S., Slovakia and some other euro area countries. However, we prefer to analyze consumer price indexes, which are more closely monitored and more relevant for the ECB monetary policy objective to maintain the price stability in the euro area. We expect higher significance level of the use of core inflation, which does not cover volatile prices of food and energy and thus contains a higher price level persistency.

What should be also noted is that the sensitivity of inflation to unit labor costs varies systematically across sectors (for example the service sector tends to have stickier prices than the manufacturing sector) and also the causality of ULC differs across sectors and implies diverse significance level of impacts on inflation dynamics. We analyze the unit labor costs of 3 economic sectors (private sector excluding agriculture, manufacturing, and market services) and the whole economy. For every country we found a specific economic sector which validated that unit labor cost dynamics drive inflation and these sectoral data were used to estimate the theoretical inflation (Tab. 2).

Table 2 Significant Economic Sectors where ULC Growth (Δulc_t) Granger Causes Inflation (π_t)

	Significant Granger Causality :		
Δulc_t	π_t (cpi)	π_t (net_cpi)	π_t (hicp)
US	total	total	-
SK	total	total	total
BE	total	total	total
LU	total	total	ms
AT	pri	ms	pri
FI	pri	ms	pri
FR	pri	pri	pri
PT	pri	pri	-
IE	ms	ms	-
NL	ms	total	total
DE	-	ms	-
ES	man	total	man

Source: Own calculations.
Explanatory note: total economy (total), private sector (pri), market services (ms), manufacturing (man).

[11] The data used were extracted from the statistical databases of OECD and EUROSTAT.

4.1 ESTIMATION METHOD

As we have already mentioned the forecasting VAR used for the estimation of $E_t \Delta ulc_{t+j}$ is estimated separately from the pricing parameters β and φ . In our estimation procedure due to Sbordone we denote X_t as the vector of the following dependent variables: the rate of change of unit labor costs and output, and the ratio of prices to unit labor costs, $X_t = \left[\Delta ulc_t \, \Delta y_t \, (p_t - ulc_t)\right]'$. Our resulting VAR model is of the form $Z_t = \Gamma Z_{t-1} + \varepsilon_{zt}$, where the vector Z_t is defined as $Z_t = \left[X_t X_{t-1}\right]'$. Because the unit labor cost growth is the first element of the vector $Z_t = \Gamma Z_{t-1} + \varepsilon_{zt}$ and $E_t Z_{t+j} = \Gamma^j Z_t$, the weighted sum of unit labor cost forecast into the future is the first element of the vector $\left[I - \lambda_2^{-1}\Gamma\right]^{-1} Z_t$. For each value of the parameters φ and β in a chosen grid we solve for $(\beta\theta)$ and compute the forecast $\sum_{j=0}^{\infty} (\beta\theta)^j E_t \Delta ulc_{t+j}$. We search for such parameter combinations which minimize the variance of the residual $e_t = \pi_t^{model} - \pi_t$ and fulfill these theoretical restrictions: $\varphi > 0$, $\beta=0.99$ *or* $\beta=0.98$ and $0<\theta<1$. We will focus also on the standard deviations of residuals of the flexible price model (eq. 2), where the lagged inflation has no significant power and compare them to the model with nominal price rigidities (eq. 5).

5 RESULTS

The minimum distance method of the two-step VAR model with a discount factor $\beta=0.99$ and constant returns to scale provides plausible degree of fit. As expected[12] the core inflation in the New Keynesian Phillips Curve performs best in comparison to the other inflation indicators. In the case of core inflation eight euro area countries (AT, BE, ES, FI, FR, DE, NL, SK) underlined the importance of the relationship between unit labor costs and price level by calculating the theoretical inflation dynamics to get a closer fit to the actual inflation. The results are given in Table 3.

The probability of equal variances between the fitted and actual inflation of the eight euro area countries was on average equal to 50% and the correlation was around the value of 0.58.[13] Even two of them (SK, BE) put more weight on flexible price model by explaining a greater part of the volatility of inflation, where we expect that the firms change their prices every quarter with respect to movements in unit labor costs. This is determined by $(1/1\text{-}\theta)=1$. For the remaining six euro area countries the average price duration period is 14 months.

[12] The results with other inflation indicators can be found in the Table A.1 in appendix.
[13] For more details see Table A.2 in appendix.

Table 3 Results (constant returns to scale, $\beta=0.99$)

core CPI	σ(e)_FLEX	σ(e)_RIG	IMPROVEMENT	(β=0.99)	φ	θ	1/(1-θ)	VAR R^2
AT	0.00258	0.00256	1%	AT	0.5387	0.4891	1.9574	0.97
ES	0.00422	0.00381	10%	ES	0.3067	0.5808	2.3855	0.99
FI	0.00615	0.00333	46%	FI	0.0098	0.9102	11.1368	0.97
FR	0.00227	0.00169	25%	FR	0.0704	0.7709	4.3656	0.90
DE	0.00368	0.00351	5%	DE	0.2823	0.5936	2.4607	0.99
NL	0.00355	0.00273	23%	NL	0.0386	0.8256	5.7337	0.98
IE	0.01247	0.00371	70%	IE	0.0031	0.9505	20.1939	0.88
LU	0.00412	0.00298	28%	LU	0	1	→ ∞	0.84
PT	0.00466	0.00312	33%	PT	0.0024	0.9565	23.0022	0.64
BE	0.00365	0.00402	-10%	BE	0.6229 (→ ∞)	0.4645 (0)	1.8673 (1)	0.95
SK	0.00759	0.00809	-7%	SK	0.7043 (→ ∞)	0.4434 (0)	1.7966 (1)	0.93
US	*0.0022*	*0.00144*	*35%*	*US*	*0*	*1*	*→ ∞*	*0.95*

Source: Own calculations
Explanatory note: σ(e)_FLEX…standard deviations of residuals e of the flexible model (2); σ(e)_RIG…standard deviations of residuals e of the model with nominal price rigidities (4); IMPROVEMENT= 1-(σ_RIG/ σ_FLEX)…measures the resulting improvement in the fit of the data due to the use of sticky prices assumption; VAR R^2…is the R squared of the VAR model used to calculate expectation of ulc growth.

However, Ireland and Portugal did not confirm a significant connection between inflation and ULC growth due to a degree of price rigidity (θ) close to one. It should be mentioned that the closer is θ to one the higher is the time needed to adjust a price and the less significant is the use of unit labor costs in the model. For Luxembourg and the U.S.[14] we have got an estimate of θ even equal 1.

Figure 1 shows the actual and fitted inflation dynamics of the eight countries were we examined that fluctuations in unit labor costs have an impact on inflation volatility. As we can see the resulting fitted inflation evaluated by using flexible or sticky price model is close to the real data. [15]

[14] For the U.S. we have got more relevant estimates under the use of CPI rather than core CPI as inflation indicator in the model.
[15] The respective residuals are plotted in figure A.1 in appendix.

Figure 1 Actual Inflation and Fitted Inflation Deviations from the Mean (π and π^*) under Flexible Price Model (_flex) or Model with Nominal Price Rigidities (_rig)

Source: Own calculation.

To get more plausible estimates of the parameter θ we use the assumption of decreasing returns to scale, where firms face increasing marginal costs, which vary across the firms. It should be noted that what actually changes is only the value of the degree of price rigidity while the behavior of the fitted inflation stays the same. Following Galí, Gertler and López-Salido (2001) who worked with euro area data we set $\alpha=0.175$ and $\epsilon=11$, and calculate the new values of the degree of nominal rigidities. The results of θ in a model with decreasing returns to scale can be found in Table 4.

Table 4 Results (constant returns to scale, $\beta=0.99$)

	α=0		α=0.175			α=0		α=0.175	
core CPI	θ	1/(1-θ)	θ	1/(1-θ)	core CPI	θ	1/(1-θ)	θ	1/(1-θ)
AT	0.4891	1.9574	**0.2855**	**1.3995**	IE	0.9505	20.1939	**0.9080**	**10.8648**
ES	0.5808	2.3855	**0.3792**	**1.6108**	PT	0.9565	23.0022	**0.9186**	**12.2787**
FI	0.9102	11.1368	**0.8390**	**6.2099**	LU	1	→∞	1	→∞
FR	0.7709	4.3656	**0.6214**	**2.6411**	BE	0.4645 (0)	1.8673 (1)	**0.2627 (0)**	**1.3564 (1)**
DE	0.5936	2.4607	**0.3935**	**1.6487**	SK	0.4434 (0)	1.7966 (1)	**0.2441 (0)**	**1.3230 (1)**
NL	0.8256	5.7337	**0.7028**	**3.3650**					

Source: Own calculations.

The average price duration period of 14 months decreased to 8 months for the countries in the euro area. It should be mentioned that the results coincide with the literature where Galí, Gertler, López-Salido (2001) estimated $\theta=0.70$ (10 months), and Lawles and Whelan (2007) $\theta=0.59$ (7.5 months).

We also tested the robustness of our results with a discount factor $\beta=0.98$. Regarding the results of the nominal price rigidity model shown in Table 5, we can say that, as expected, lowering the value of β led to more price stickiness and an improvement in the standard deviation of the estimated residuals. The estimated parameters of seven of the above mentioned eight euro area countries remained quite robust and the degree of price stickiness changed on average by 1%. Only Netherlands did not coincide with the robustness of the estimated parameters and the value of θ increased by 15%. The most robust results are for Austria followed by Finland and Germany. Finally we have to say that on average the standard deviation of the estimated residuals did improve only by 0.30% and so in the case of Belgium and Slovakia, the residual improvement in the sticky price model was not sufficient to cover the better fitness of the model with flexible prices.

Table 5 Results with $\beta=0.98$ in Comparison to $\beta=0.99$

		(β=0.99)	(β=0.98)	**(β=0.99)**		(β=0.98)		θ - change
core CPI	σ(e)_FLEX	**σ(e)_RIG**	σ(e)_RIG	**θ**	**1/(1-θ)**	θ	1/(1-θ)	in %
AT	0.002584	**0.002557**	0.002553	**0.4891**	**1.9574**	0.4913	1.9658	0.45
impr.		**1.04%**	1.20%					
ES	0.004223	**0.003806**	0.003793	**0.5808**	**2.3855**	0.5852	2.4108	0.76
impr.		**9.87%**	10.18%					
FI	0.006151	**0.003325**	0.00331	**0.9102**	**11.1368**	0.9045	10.4712	-0.63
impr.		**45.94%**	46.19%					
FR	0.002271	**0.001693**	0.001682	**0.7709**	**4.3656**	0.7849	4.649	1.82
impr.		**25.45%**	25.94%					
DE	0.003675	**0.003507**	0.003501	**0.5936**	**2.4607**	0.5980	2.4876	0.74
impr.		**4.57%**	4.73%					
NL	0.003550	**0.002727**	0.002664	**0.8256**	**5.7337**	0.9505	20.202	15.13
impr.		**23.18%**	24.96%					
BE	0.003648	**0.004024**	0.004014	**0.4645**	**1.8673**	0.4734	1.899	1.92
impr.		**-10.31%**	-10.03%	**0**	**1**			
SK	0.007592	**0.008089**	0.008081	**0.4434**	**1.7966**	0.4472	1.809	0.86
impr.		**-6.55%**	-6.44%	**0**	**1**	0	1	

Source: Own calculations.
Explanatory note: σ(e)_FLEX…standard deviations of residuals e of the flexible model (2); σ(e)_RIG…standard deviations of residuals e of the model with nominal price rigidities (4); IMPR.= 1-(σ_RIG/ σ_FLEX)…measures the resulting improvement in the fit of the data due to the use of sticky prices assumption.

6 Conclusion

The purpose of our study was to analyze the relationship between the unit labor costs and inflation. We estimated an optimal price path model individually for eleven euro area countries under two-step approach methodology. We searched for a model that minimized the distance between fitted and actual price level fluctuations with parameters which satisfied theoretical restrictions.

We found that inflation and unit labor costs as an indicator of marginal costs move largely together. Following our expectations about inflation indicators the use of core inflation in the New Keynesian Phillips Curve was the most significant one. In line with this fact in eight of eleven euro area countries observed the theoretical inflation dynamics indicated a plausible relationship between unit labor costs and price level. Estimated average time needed to adjust quite flexible prices in line with movements in unit labor costs was around eight months.

Slovakia was specific in the sense of putting more weight on the flexible price model, but with the highest standard deviations in comparison to the better fit of the theoretical inflation of the other euro area countries. Despite the high level of uncertainty this estimation result coincides also with analyses of Gertler and Senaj (2008) on downward wage rigidities in Slovakia based on micro foundations, where they detected rather flexible nominal compensations. However, especially for Slovakia, it is important in the future to think about a model which will cover also the openness of a small economy and the implied impact of imported inflation.

REFERENCES

Batini, N., Jackson, B., Nickell, S., 2005. An Open-Economy New Keynesian Phillips Curve for the U.K.. Journal of Monetary Economics 52, pp. 1061-1071

Calvo, G.A., 1983. Staggered Prices in a Utility-Maximizing Framework. Journal of Monetary Economics 12, pp. 383-398

Christoffel, K., Kuester, K., Linzert, T., 2009. The Role of Labor Markets for Euro Area Monetary Policy. Kiel Institute for the World Economy. Kiel Working Paper No.1513 / March 2009.

Galí, J., Gertler, M., 1999. Inflation Dynamics: A Structural Econometric Analysis. Journal of Monetary Economics 44, pp. 195-222

Galí, J., Gertler, M., López-Salido, J.D., 2001. European Inflation Dynamics. National Bureau of Economic Research, NBER Working Paper Series, Working paper 8218

Galí, J., Gertler, M., López-Salido, J.D., 2005. Robustness of the estimates of the hybrid New Keynesian Phillips curve. Journal of Monetary Economics 52, pp. 1107-1118

Galí, J., Gertler, M., 2007. Macroeconomic Modeling for Monetary Policy Evaluation. Journal of Economic Perspectives, Volume 21, pp. 25-45

Gertler P., Senaj M. 2008. Downward Wage Rigidities in Slovakia. National Bank of Slovakia. Working Paper No. 7/2008.

- downloadable at http://www.nbs.sk/_img/Documents/PUBLIK%5C08_KOL5A.PDF

Kurmann, A., 2005. Quantifying the Uncertainty about the Fit of a New Keynesian Pricing Model. Journal of Monetary Economics 52, pp. 1119-1134

Lawless, M., Whelan, K., 2007. Understanding the Dynamics of Labor Shares and Inflation. European Central Bank, Working Paper Series, NO 784

Lindé, J., 2005. Estimating New-Keynesian Phillips Curves: A Full Information Maximum Likelihood Approach, Journal of Monetary Economics 52, pp. 1135-1149

Paloviita, M., 2004. Inflation Dynamics in the Euro Area and the Role of Expectations: Further Results. Bank of Finland Discussion Papers 21/2004

Rabanal, P., Rubio-Ramírez, J.F., 2005. Comparing New Keynesian Models of the Business Cycle: A Bayesian approach. Journal of Monetary Economics 52, pp. 1151-1166

Rotemberg, J.J., 1982. Sticky Prices in the United States, The Journal of Political Economy. Vol.90, No.6., pp. 1187-1211

Rotemberg, J.J., Woodford, M., 1999. The Cyclical Behavior of Prices and Costs. Handbook of Macroeconomics, Volume 1, Elsevier Science B.V., pp. 1051-1135

Rudd, J., Whelan, K., 2002. Should Monetary Policy Target Labor's Share of Income? Finance and Economic Discussion Series, Board of Governors of the Federal Reserve System (U.S.), Second Draft

Rudd, J., Whelan, K. 2005. New Test of the New-Keynesian Phillips curve. Journal of Monetary Economics 52, pp.1167-1181

Sbordone, A., 1998. Prices and Unit Labor Costs: A New Test of Price Stickiness. Institute for International Economic Studies, Stockholm University, Seminar Paper No. 653.

Sbordone, A., 2002. Price and Unit Labor Costs: A New Test of Price Stickiness. Journal of Monetary Economics 49, pp. 265-292

Sbordone, A., 2005. Do Expected Future Marginal Costs Drive Inflation Dynamics? Journal of Monetary Economics 52, pp. 1183-1197

Tillman, P., 2005. The New Keynesian Phillips Curve in Europe: Does It Fit or Does It Fail? Deutsche Bundesbank, Discussion Paper No 04/2005

Woodford, M., 2001. The Taylor Rule and Optimal Monetary Policy. American Economics Review 91, pp. 232-237

Woodford, M., 2003. Interest and Prices: Foundation of a Theory of Monetary Policy. Princeton University Press.

APPENDIX

The evaluation of the eq. 3 due to Sbordone (1998)

$$\pi_t = \beta E_t \pi_{t+1} + \varphi\, rmc_t$$

$$\pi_t = \beta E_t \pi_{t+1} + \varphi (ulc_t - p_t)$$

$$(ulc_t - p_t) = \varphi^{-1}(\pi_t - \beta E_t \pi_{t+1})$$

$$ulc_t = (1 + \varphi^{-1} + \beta\varphi^{-1}) p_t - \varphi^{-1} p_{t-1} - \varphi^{-1} \beta E_t p_{t+1}$$

$$ulc_t = -\varphi^{-1} \beta E_t \left(1 - \frac{\varphi + \beta + 1}{\beta} L + \frac{1}{\beta} L^2 \right) p_{t+1}$$

$$ulc_t = -\varphi^{-1} \beta E_t ((1 - \lambda_1 L)(1 - \lambda_2 L)) p_{t+1}$$

Where λ_1 and λ_2 are two roots of the polynomial $P(\lambda)$: $P(\lambda) = \beta\lambda^2 - (1 + \beta + \varphi)\lambda + 1 = 0$.

Implying $\lambda_1 = \theta,\ \lambda_2 = 1/\beta\theta$ and φ which underlie following restrictions: $\varphi^{-1} > 0$, $0 < \beta < 1$, $0 < \lambda_1 < 1$ and $\lambda_2 > \beta^{-1} > 1$

Defining $x_{t+1} = (1 - \lambda_1 L) p_{t+1}$, we can rewrite ulc_t as

$$ulc_t = (\varphi^{-1} \beta \lambda_2) x_t - (\varphi^{-1} \beta) E_t x_{t+1}$$

The use of the equality $(\varphi^{-1} \beta \lambda_2)^{-1} = (1 - \lambda_1)(1 - \lambda_2^{-1})$ and solving forward we get

$$x_t = (1 - \lambda_1)(1 - \lambda_2^{-1}) \sum_{j=0}^{\infty} \lambda_2^{-1} E_t (ulc_{t+j})$$

$$p_t = \lambda_1 p_{t-1} + (1 - \lambda_1)(1 - \lambda_2^{-1}) \sum_{j=0}^{\infty} \lambda_2^{-j} E_t (ulc_{t+j})$$

Using the fact that

$$E_t \sum_{j=0}^{\infty} \lambda_2^{-j} ulc_{t+j} = \frac{1}{(1 - \lambda_2^{-j})} (ulc_t + E_t \sum_{j=0}^{\infty} \lambda_2^{-j} ulc_{t+j})$$

We get the equation 3:

$$p_t = \lambda_1 p_{t-1} + (1 - \lambda_1) ulc_t + (1 - \lambda_1) \sum_{j=0}^{\infty} \lambda_2^{-j} E_t \Delta ulc_{t+j}$$

Table A.1 Results for Other Inflation Indicators (constant returns to scale, $\beta=0.99$)

CPI	σ(e)_FLEX	σ(e)_RIG	IMPROVEMENT	(β=0.99)	φ	θ=λ1	1/(1-θ)	VAR R^2
AT	0.00337	0.00312	7%	AT	0.1342	0.6975	3.3061	0.95
BE	0.0047	0.00456	3%	BE	0.3487	0.5607	2.2761	0.95
PT	0.00522	0.00378	28%	PT	0.0175	0.8801	8.3394	0.6
ES	0.00685	0.00405	41%	ES	0.0002	0.9894	94.458	0.95
FI	0.00398	0.00313	21%	FI	0.0025	0.9559	22.6685	0.95
IE	0.01322	0.00393	70%	IE	0	1	→ ∞	0.88
LU	0.00459	0.0043	6%	LU	0	1	→ ∞	0.84
NL	0.00407	0.00275	33%	NL	0	1	→ ∞	0.98
FR	0.00245	0.0027	-10%	FR	1.2981 (→ ∞)	0.3387 (0)	1.5121 (1)	0.9
SK	0.01033	FLEX ←		SK	→ ∞	0	1	0.93
US	*0.00323*	*0.00335*	*-4%*	*US*	*1.5975* *(→ ∞)*	*0.3043* *(0)*	*1.4374* *(1)*	*0.95*
HICP	σ(e)_FLEX	σ(e)_RIG	IMPROVEMENT	(β=0.99)	φ	θ	1/(1-θ)	VAR R^2
AT	0.00322	0.00269	16%	AT	0.0471	0.8088	5.2306	0.95
BE	0.00517	0.00486	6%	BE	0.315	0.5767	2.3622	0.95
FI	0.00419	0.00302	28%	FI	0.0076	0.921	12.655	0.98
NL	0.00336	0.00306	9%	NL	0.1092	0.7227	3.6059	0.9
ES	0.00734	0.00256	65%	ES	0.0007	0.979	47.729	0.95
LU	0.00887	0.00627	29%	LU	0	1	→ ∞	0.77
FR	0.00267	0.00305	-14%	FR	3.0908 (→ ∞)	0.205 (0)	1.2579 (1)	0.95
SK	0.01009	FLEX ←	0%	SK	→ ∞	0	1	0.93

Source: Own calculations.
Explanatory note: σ(e)_FLEX…standard deviations of residuals e of the flexible model (2); σ(e)_RIG…standard deviations of residuals e of the model with nominal price rigidities (4); IMPROVEMENT= 1-(σ_RIG/ σ_FLEX)…measures the resulting improvement in the fitness of the data due to the use of sticky prices assumption; VAR R^2...is the R squared of the VAR model used to calculate expectation of ulc growth.

Table A.2 Standard deviations of residuals $\sigma(e)$, probabilities of variance σ^2 equality and correlations ρ between fitted (π *) and actual (π) inflation

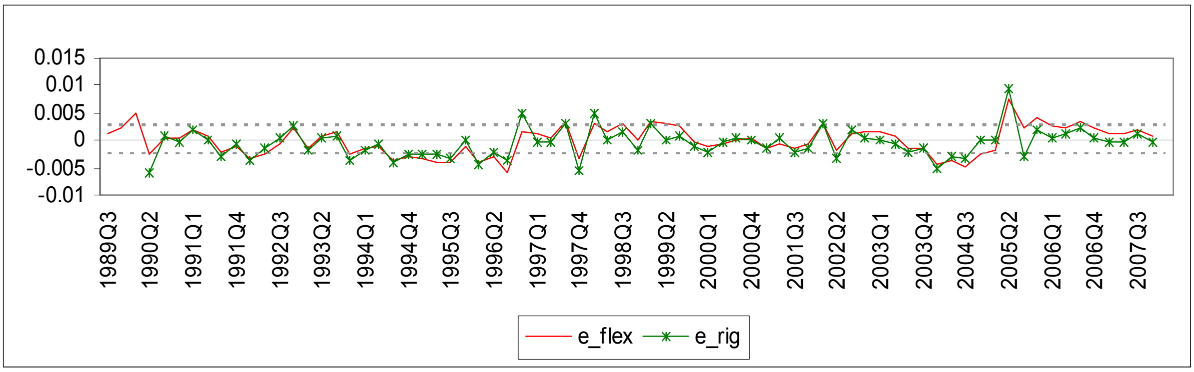
	e=(π*-π)			Probability of σ²(π *)=σ²(π)			Correlation ρ(π*,π)		
core CPI	σ(e)_FLEX	**σ(e)_RIG**	IMPROVEMENT	σ²_FLEX	**σ²_RIG**	IMPROVEMENT	ρ_FLEX	**ρ_RIG**	IMPROVEMENT
AT	0.00258	**0.00256**	YES	0.21	**0.44**	YES	0.63	**0.65**	YES
ES	0.00422	**0.00381**	YES	0.17	**0.46**	YES	0.76	**0.68**	NO
FI	0.00615	**0.00333**	YES	0.01	**0.89**	YES	0.68	**0.36**	YES
FR	0.00227	**0.00169**	YES	0.58	**0.2**	NO	0.53	**0.72**	YES
DE	0.00368	**0.00351**	YES	0.64	**0.66**	YES	0.66	**0.67**	YES
NL	0.00355	**0.00273**	YES	0.00	**0.67**	YES	0.48	**0.53**	YES
IE	0.01247	**0.00371**	YES	0.00	**0.63**	YES	0.12	**0.66**	YES
LU	0.00412	**0.00298**	YES	0.02	**0.98**	YES	0.44	**0.52**	YES
PT	0.00466	**0.00312**	YES	0.20	**0.44**	YES	0.18	**0.28**	YES
BE	0.00365	**0.00402**	NO	0.01	**0.05**	YES	0.60	**0.45**	NO
SK	0.00759	**0.00809**	NO	0.60	**0.59**	NO	0.57	**0.56**	NO
US	*0.0022*	***0.00144***	*YES*	*0.15*	***0.95***	*YES*	*0.65*	***0.83***	*YES*

Source: Own calculations .

Explanatory note: σ(e)_FLEX…standard deviations of residuals e of the flexible model (2); σ(e)_RIG…standard deviations of residuals e of the model with nominal price rigidities (4); IMPROVEMENT…measures the resulting improvement in the fitness of the data due to the use of sticky prices assumption.

Figure A.1 Residuals (e) with their Standard Deviations under Flexible Price Model (_flex) or Model with Nominal Price Rigidities (_rig)

AT



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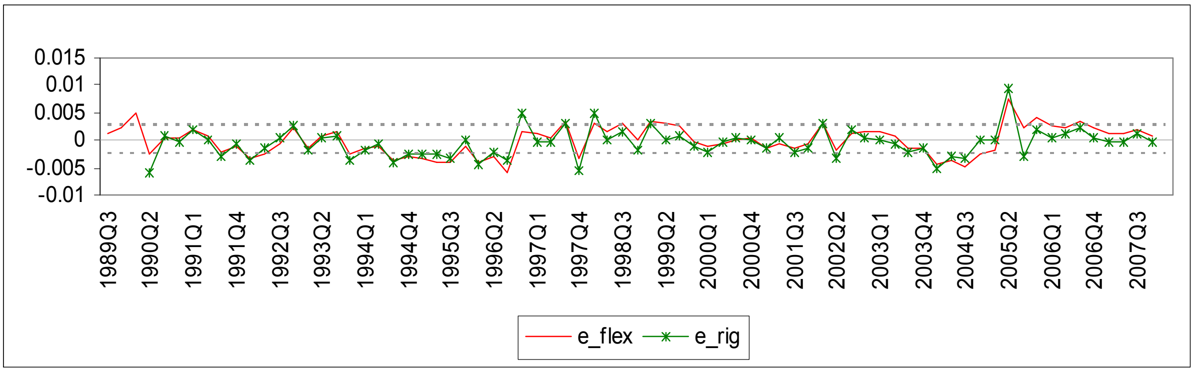

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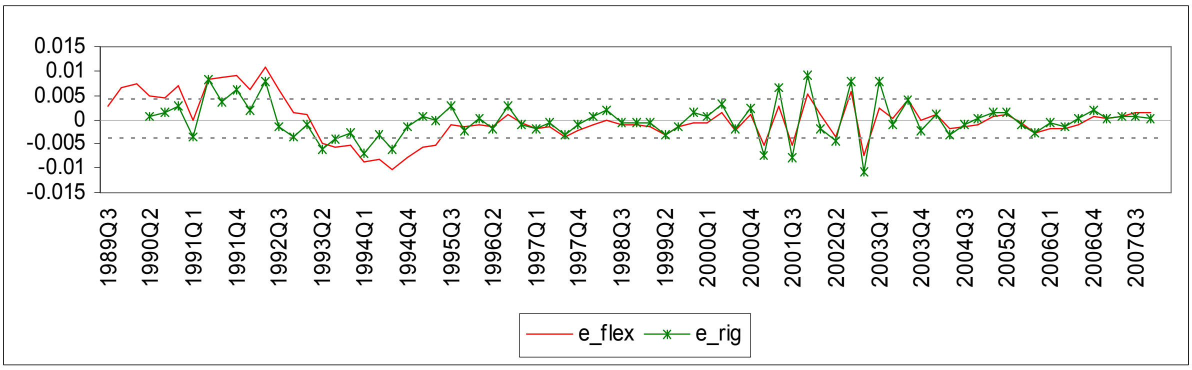
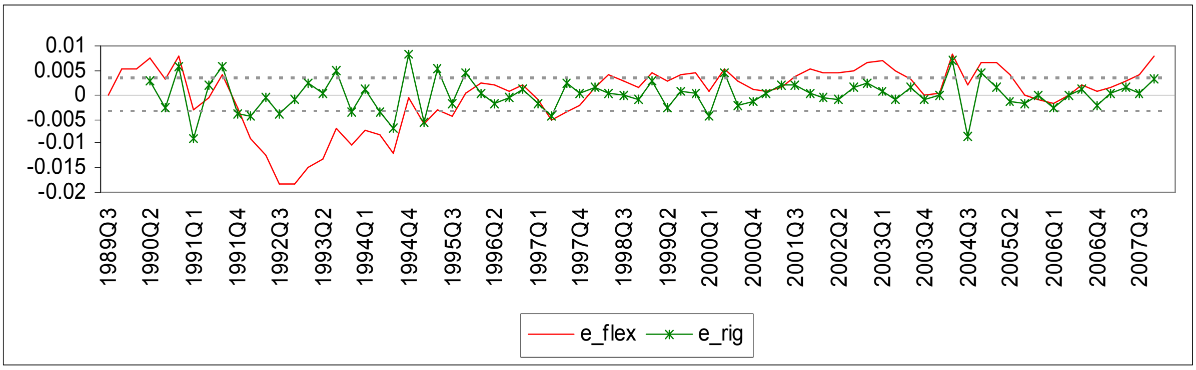


FI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2000Q1
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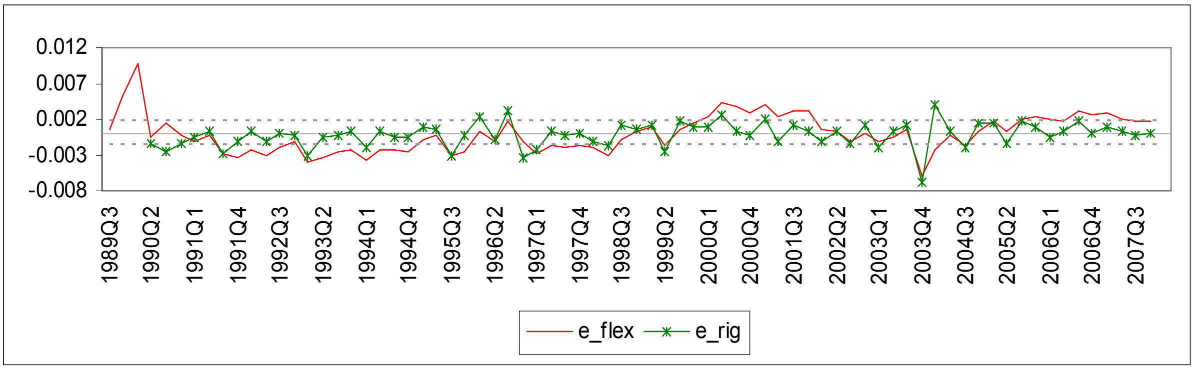
2006Q4
2007Q3
e_flex
e_rig

FR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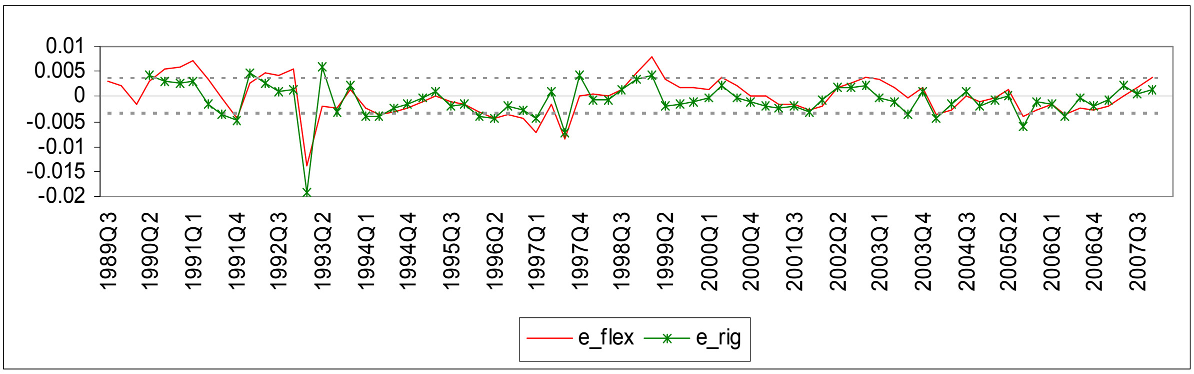
e_flex
e_rig

DE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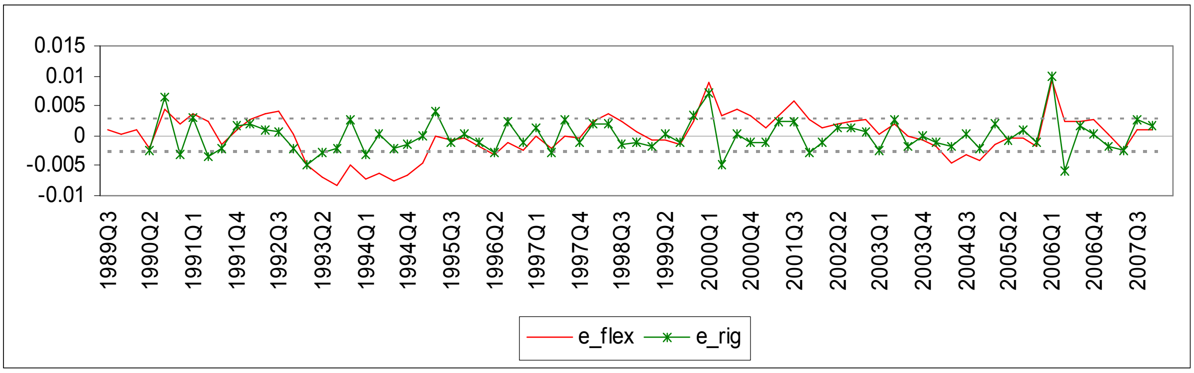
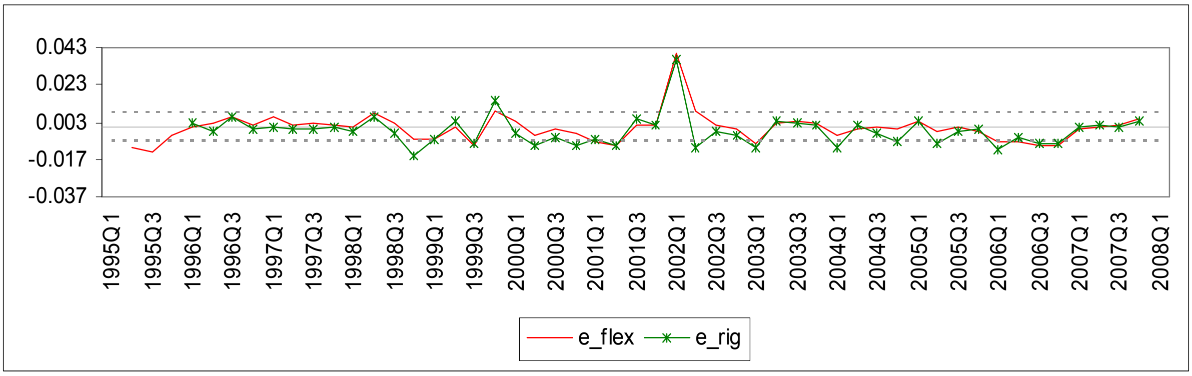
NL



SK



Source: Own calculations.