COMENIUS UNIVERSITY, BRATISLAVA
Faculty of Mathematics, Physics and Informatics

Mathematics of Economics and Finance

The New Keynesian Phillips Curve
The comparison of new member states

MASTER THESIS

Katarína Bakošová

Bratislava 2007

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Nová Keynesiánska Phillipsova Krivka
Porovnanie nových členských štátov

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I declare this thesis was written on my own, with the only help provided by my supervisor and the referred-to literature.

Bratislava, April 25, 2007 ....

Katarína Bakošová

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Abstract

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The New Keynesian Phillips Curve has become an important part of monetary policy models. It describes the relationship between inflation and real marginal cost with focusing on the forward-looking and the backward-looking behavior of subjects on the market. The master thesis is dedicated to the estimation of this curve for selected new member states (Slovak Republic, Czech Republic, Poland and Hungary) using Generalized Method of Moments. Estimation of the New Keynesian Phillips Curve determines the importance of real marginal cost, forward-looking and backward-looking behaviour in inflation dynamics and degree of price stickiness.

Keywords: inflation, output gap, marginal costs, real unit labour costs,
Keynesian Phillips Curve

Abstrakt

BAKOŠOVÁ, Katarína: Nová Keynesiánska Phillipsova Krivka; Porovnanie nových členských štátov EU [diplomová práca]. Univerzita Komenského, Bratislava. Fakulta Matematiky, Fyziky a Informatiky; Katedra Aplikovanej Matematiky a Štatistiky. Vedúci diplomovej práce: Doc.Dr.Jarko Fidrmuc, Katedra ekonómie, Mníchovská Univerzita. Bratislava: FMFI UK, 2007. 81 strán

Nová Phillipsova Krivka sa stala dôležitou súčasťou modelov monetárnej politiky. Popisuje vzťah medzi infláciou a reálnymi hraničnými nákladmi so zameraním sa na využitie minulej informácie a očakávanej informácie o budúcom vývoji na trhu pri stanovovaní ceny. Diplomová práca sa zaoberá odhadom tejto krivky pre vybrané nové členské štáty (Slovensko, Česko, Poľsko a Maďarsko) s použitím GMM (Generalized Method of Moments). Tento odhad stanovuje dôležitosť reálnych hraničných nákladov a využitej informácie ako determinantov inflačného vývoja a určuje stupeň inflačnej zotrvačnosti (t.j. priemernú dobu, počas ktorej ceny ostávajú nezmenené).

Keywords: inflácia, produkčná medzera, hraničné náklady, reálne jednotkové náklady práce, Keynesiánska Phillipsova Krivka

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Chapter 1

Introduction

Inflation dynamics and the nature of short-run inflation have been very debated issues over the years. Phillips (1958) initiated the discussion that has not been completed yet. Recent theoretical advances have produced alternative views of the inflation process with crucially different implications for optimal monetary policy.

The new inflation literature is built on the work of Fischer (1977), Taylor (1980) and Calvo (1983) and emphasizes the forward-looking behaviour of subjects on the market and sticky prices framework. One of the key New Keynesian models based on these assumptions is generally known as the New Keynesian Phillips Curve. The term was used for the first time by Roberts (1995) and empirically supported by Sbordone (1998, 2001) and Galí et al. (1999, 2001). The latter authors also pioneered the estimation of the New Hybrid Keynesian Phillips Curve to capture the inflation persistence. Findings of Galí et al. encourage the use of this dynamic general equilibrium models in monetary policy analysis as they suggest that the observed dynamics of inflation can be understood with models derived from microeconomic foundations (Neiss et al. (2002)).

The New Keynesian Phillips Curve has two distinct features that characterize the relationship between inflation and economic activity. At first, it is forward-looking character of inflation that is a consequence of the fact that firms set prices on the basis of their expectations about the future evolution of demand and cost factors. The second feature involves the link between inflation and real activity, which comes through the potential effects of the latter on real marginal cost. The hybrid case of the New Keynesian Phillips Curve (The New Hybrid Keynesian Phillips Curve) allows a subset of firms to use the backward-looking rule of thumb to set prices and introduce the lagged inflation term to the former equation. Coefficients of this model are functions of three structural parameters: probability of price adjustment, the share of forward-looking firms on the market and subjective discount factor.

Contribution of this thesis is in the estimation of the New Keynesian Phillips Curve and the New Hybrid Keynesian Phillips Curve for selected new member states: Slovak Republic, Czech republic, Hungary and Poland. All estimated countries have overcome the transformation process from central planned economy to market economy. Therefore time series are short and reflect structural changes that accompanied the process of transformation. Consequently, some assumptions in our estimation process are not fulfilled, what creates additional problems with regard to the estimation.

Empirical estimations generally use the output gap and real unit labor costs as a proxy variables for the real marginal cost, since real marginal cost's time series are not available. In this context, we employed Generalized Method of Moments due to measurement and/or simultaneity problems. As we show, several results stand out and appear to be quite robust.

The thesis is organized as follows: Chapter 2 provides a characterization of the traditional Phillips Curve and summarizes main reasons of its failure. In Chapter 3 we present the derivation of the New Keynesian Phillips Curve and its hybrid case. Chapter 4 is dedicated to the brief review of literature, where we emphasize the main findings and conclusions in the Keynesian Phillips Curve's theory and estimations. Chapter 5 presents Generalized Method of Moments employed in the estimation of the New Keynesian Phillips Curve. In Chapter 6 we describe our data set. Finally in Chapter 7 we present obtained results and we conclude in Chapter 8.

Chapter 2

The Critique of the Standard Phillips Curve

2.1 The Standard Phillips Curve

The Phillips Curve has been one of the central models in macroeconomics since it was presented by *A.W.Phillips* in his paper *"The Relationship Between Unemployment and the Rate of Price Change of Money Wage Rates in the United Kingdom, 1862–195"* published in *Economica* (see Phillips (1958)). He observed and documented an inverse statistical relationship between the wage inflation and the rate of unemployment over the business cycle. According to his paper, while unemployment was high, nominal wages increased slowly and when unemployment was low, nominal wages rose rapidly except for the period of volatile inflation between two world wars. Low rates of unemployment pressured the labor market to offer higher wages while higher rates of unemployment allowed employers to lower wages.

Two years later *Paul Samuelson* and *Robert Solow* demonstrated the equivalent relation between price inflation and unemployment since wages are closely connected to prices settled by companies (see Samuelson and Solow (1960)).

The Phillips Curve became an important part of the standard Keynesian model and central to macroeconomic thinking and policy. Ignoring episodes as the Great Depression, countries could choose between different combinations of unemployment and inflation. The concept was based on an argument that the price level stability (zero inflation) could be obtained by allowing higher unemployment or otherwise low unemployment could be substituted by tolerating high inflation. Thus, demand management policies could be applied to stimulate economy, raise output at the expense of higher inflation. Moving along the Phillips Curve would lead to lower rates of unemployment.

On the figure 2.1, there is one example of the Phillips Curve applied on the US data for the period 1960-1969.

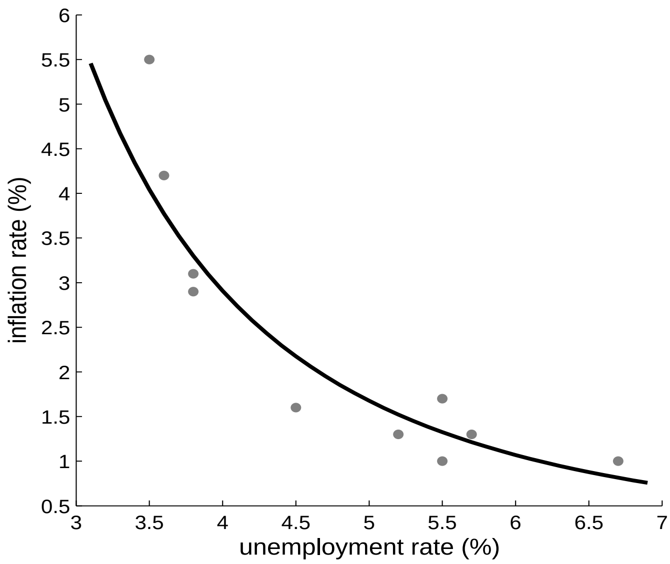

Figure 2.1: Modified Phillips Curve for USA 1960-1969
(Source: our calculations using database from program Gretl (see Gretl))

2.2 The Critique of the Phillips Curve

An alternative understanding of the Phillips curve was emerging in late 1960s. In 1968, *Milton Friedman* presented his view of the Phillips Curve addressed to the American Economic Association (see Friedman (1968)).[1] He criticized the absence of rational expectations and also pointed out that keeping output above its "potential" level (e.g. under demand management policy) would lead to the moment, when well-informed, rational employers and workers paying attention only to real wages, would require higher growth of nominal wages. The consequence of this would be the growth of unemployment rate.

Milton Friedman did not share a general view and he predicted major changes before they happened. Talking about Phillips Curve, he said:

> ...there is always a temporary trade-off between inflation and unemployment; there is no permanent trade-off. The temporary trade-off comes not from inflation per se, but from a rising rate of inflation.

His analysis and also the work of another American economist *Edmund Phelps*[2] (see Phelps (1967)) provide a distinction between the short-term and the long-term Phillips Curve, which is based on hypothesis of the "natural level" of unemployment later exerted as *NAIRU* (non-accelerating inflation rate of unemployment). The Friedman's hypothesis assumes that *NAIRU* is the unique rate of unemployment succeeded by stable inflation rate.

In his view government could not perform permanent trade-off between unemployment and inflation rates in the long run. As long as inflation remains more or less constant in the short run (as it did in the sixties), it is negatively related to the unemployment. As soon as the inflation rate changes, after a period of adjustment the rate of unemployment will return to the *NAIRU* regardless of the height of the inflation rate.

[1] In 1976 Milton Friedman received the Nobel price for his achievements in the fields of consumption analysis, monetary history and theory and for his demonstration of the complexity of stabilization policy

[2] In 2006 Edmund Phelps received Nobel price for his analysis of intertemporal tradeoffs in macroeconomic policy, i.e. deepening the understanding of the relation between short-run and long-run effects of economic policy and his contributions to a decisive impact on economic research as well as policy.

For better explanation we can imagine that unemployment is at the natural level and the real wage is constant. Workers expect a given rate of price inflation and bargain the same growth of nominal wages to prevent the erosion of their purchasing power. As soon as the government uses expanding monetary policy to lower unemployment below its natural level, increase in demand encourage companies to rise prices more then workers anticipate. Under higher revenues companies hire more employees at the same wage and possibly rise wages in nominal terms. Thus, the unemployment rate falls. For a short time employees have so called the money illusion, that their purchasing power has risen. In reality, contrary is the case, because the price inflation is higher than the wage inflation. Right after they realize it, they offer less labor, which puts a pressure to employers to rise nominal wages. The real wage is restored at the previous level and the rate of unemployment returns to the natural level. But the price and the wage inflation stay at the new growth rate. In the long run, the only effect of such stimulus of the government will be higher inflation for the same level of unemployment. Once, workers' expectations of the price inflation have had time to adjust, the natural level of unemployment is compatible with any rate of inflation. And the more quickly workers' expectations of the price inflation adapt to changes in the actual rate of inflation, the less successful the government will be in reducing unemployment through monetary and fiscal policy.

As a result, the short-term Phillips Curve is equal to the original Phillips Curve and appears from (see Friedman (1968), Blanchard (2000))

$$\pi_t = \pi_t^e + (\mu + z) - \alpha u_t \tag{2.1}$$

where π_t denotes the inflation rate defined as the rate of change of prices from the last year to this year, π_t^e denotes the corresponding expected inflation rate, μ is the markup set by firms, z stands for all other factors that affect wage determination, u_t is the unemployment rate and coefficient $\alpha > 0$.

While the average inflation was close to zero during much of the period that Phillips was examining, it was reasonable for him to expect that inflation will be equal to zero over the next year as well. Assuming $\pi_t^e = 0$ in the previous equation gives us the short-term Phillips Curve[3] (Figure 2.2)

$$\pi_t = (\mu + z) - \alpha u_t \tag{2.2}$$

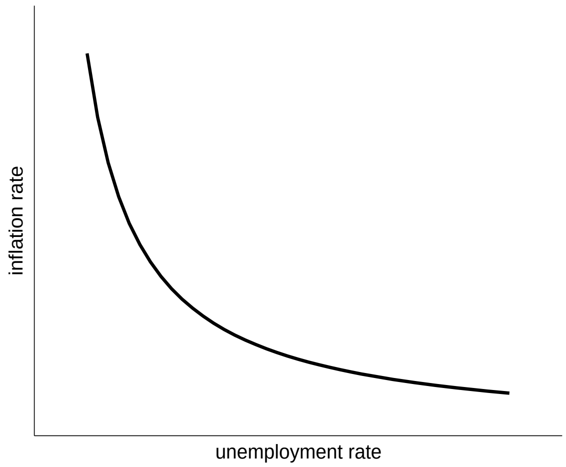

Figure 2.2: Short-term Phillips Curve

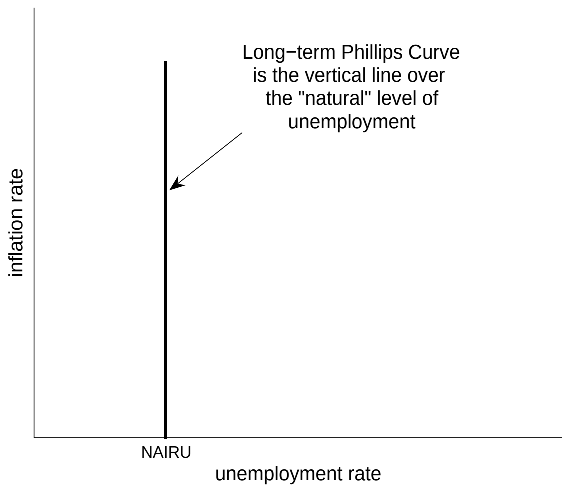

Figure 2.3: Long-term Phillips Curve

[3]We are discussing an inner linear path of the short-term Phillips Curve, which is usually hyperbolic shaped.

But according to Friedman, the short-term Phillips Curve does not hold in the long run. The long run relation between the rates of inflation and unemployment defines the long-term Phillips Curve (Figure 2.3), which is a vertical line above the natural level of unemployment. In other words, once unemployment falls to the natural rate, expansionary policies will not push it any lower except for brief, transitional periods.

Consequently Milton Friedman combined these short-term and long-term relations in a single *modified (expectations-augmented) Phillips Curve* where expected inflation rate is formed as a correction of lagged inflation

$$\pi_t^e = \theta\pi_{t-1}$$

Then (2.1) can be rewritten in the following way

$$\pi_t = \theta\pi_{t-1} + (\mu + z) - \alpha u_t \tag{2.3}$$

And by the 1970s there is the evidence, that people form their expectations of actual inflation rate to remain at last year's level. Therefore, variable θ in the *modified Phillips Curve* is equal to 1 (see Blanchard (2000)) and yields

$$\pi_t - \pi_{t-1} = (\mu + z) - \alpha u_t \tag{2.4}$$

As it can be seen now the unemployment rate affects not the inflation rate, but rather the *change* in the inflation rate. Thus, high unemployment leads to decreasing inflation rates and vice versa.

And since the *NAIRU* is non-accelerating inflation rate of unemployment, if the unemployment rate is equal to the *NAIRU* ($u_t = u_n$) then current inflation rate is equal to the expected inflation rate ($\pi_t = \pi_t^e = \pi_{t-1}$). From this claim we are able to obtain the *NAIRU* and arrive from (2.4) to the final form of the *modified Phillips Curve*:

$$\pi_t - \pi_{t-1} = -\alpha(u_t - u_n) \tag{2.5}$$

where $\alpha > 0$ and u_n is the NAIRU equal to

$$u_n = \frac{\mu + z}{\alpha}$$

Consequently, deviation of unemployment rate at the time t from the *NAIRU* is given by the difference between inflation rate and expected inflation rate at the time t. The Friedman's *modified Phillips Curve* was universal because it described the trade-off between unemployment and inflation rate even in the short or long run while the standard Phillips Curve could be applied only for a short period.

2.3 Stagflation and Neo-Keynesian Macroeconomics

The claim of *Milton Friedman* and weakness of the Phillips Curve was substantiated in 1970s, when the period of high inflation and high unemployment rate was observable. This became to be known as *stagflation*. *Robert Lucas* and *Thomas Sargent* (see Lucas and Sargent (1978)) reproached the ignorance of expectations on behaviour.[4] The way to proceed, they argued, was to assume that people formed expectations as rationally as they could, based on the information they had.

The principal response of Keynesian economists to these theoretical critics has been an attempt to build models that incorporate rational expectations[5]. They analyzed the whole basis for Keynesian economics (e.g. the assumption that monetary policy could systematically affect output even in the short-run), relied more on microeconomic foundations and incorporated them into macroeconomic models. This combination of rational expectations and microfoundations is known as *Neo-Keynesian macroeconomics* which relies crucially on the term *sticky prices* or the so-called *price rigidities*.

Without price rigidities, it is difficult to explain, that there can be a time

[4]In 1995 Robert Lucas received the Nobel price for having developed and applied the hypothesis of rational expectations, and thereby having transformed macroeconomic analysis and deepened our understanding of economic policy.

[5]Rational expectations are the optimal forecast that make efficient use of all available information.

during which factors of production, such as labor, are under-utilized and consequently output is under its "potential level". Sticky prices allow money stock increase to cause a short-run increase in real spending and thus support real output. Eventually, fiscal and monetary policy has no effect if prices are fully flexible.

We will now describe one of the New Keynesian models based on the argument of sticky prices and using the concept of the *Calvo pricing*.

Chapter 3

The Reconstruction of Macroeconomics and New Keynesian Phillips Curve

3.1 The New Keynesian Phillips Curve

The New Keynesian Phillips Curve is one of the key New Keynesian models. It is derived from Calvo sticky-pricing model (see Calvo, 1983). Even though there are more realistic formulations (see Taylor (1980) and Fischer (1977)), Calvo pricing is more comfortable, simple and gives very similar results in comparison to more complicated models. We derive the New Keynesian Phillips Curve following Galí et al. (1999).

3.1.1 Calvo Pricing

Galí et al. (1999) consider a continuous environment of monopolistically competitive firms.[1] These firms are basically identical with the exception of

[1]Monopolistically competitive markets have the following characteristics: there are many producers and many consumers in a given market; consumers have clearly defined preferences and sellers attempt to differentiate their products from those of their competitors, the goods and services are heterogeneous; there are few barriers to entry and exit;

differentiated products and pricing history. Also each faces a conventional constant price elasticity of demand curve for its own product. Their pricing decision is based on a monopolistic competitor's profit maximization problem according to the constraint of time dependent price adjustment.

Let $1-\theta$ be a random fraction of firms that are going to adjust their price in any given period.[2] It can also be interpreted as fixed probability that the firm will adjust its price in a given period. Thus, θ is the measure of price-stickiness. If $\theta = 0$, it means no price rigidities, every firm updates its price every period.

Consequently the average time during which the price remains unchanged is equal to[3]

$$(1-\theta)\sum_{k=0}^{\infty} k\theta^{k-1} = \frac{1}{1-\theta} \tag{3.1}$$

where k is the period number. In other words, the average time is equal to the weighted average of periods' numbers, where weights are probabilities that prices will be fixed for $(k-1)$ periods and changed in the period k.

Then every firm i on the market sets its price P_{it} at the time t and the new aggregate price level P_t settled at time t can be computed as follows

$$P_t = \left(\int_0^1 P_{it}^{1-\eta} di\right)^{\frac{1}{1-\eta}}$$

Since firms are identical ex ante, let Z_t^* be the optimal reset price defined by the $(1-\theta)$-fraction of firms that are able to change their price in the period t. On the other hand the price settled by the θ-fraction of firms that do not change the price is equal to the price from preceeding period. Consequently the previous expression might be rewritten as

$$P_t = \left((1-\theta)(Z_t^*)^{1-\eta} + \theta P_{t-1}^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{3.2}$$

producers have a degree of control over price on the market.

[2]Parameter θ is from the interval $(0,1)$.

[3]If $\theta = 0.5$ in a quarterly model then the average time prices are fixed is the half of a year.

A log-linearization of (3.2) around a zero inflation steady-state yields[4]

$$p_t = (1-\theta)z_t^* + \theta p_{t-1} \tag{3.3}$$

where p_t and z_t^* are percent deviations from their zero-inflation steady states.[5]

Thus, the aggregate price level on the market is a convex combination of the last year's price level and the optimal reset price regarding θ. So far, we do not know the value of the optimal reset price z_t^*. Its derivation is presented in the next section (see also Whelan (2005)).

3.1.2 The Optimal Reset Price

Firms are trying to minimalize the value of their future losses expressed by loss functions and in such way find the optimal value of the reset price. The loss functions are identical and they have the following form

$$L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t(z_t - p_{t+k}^*)^2$$

where $\beta \in (0,1)$ is a subjective discount factor, z_t is the reset price, p_t^* is the optimal price that firm would set at the time t if there were no price rigidities and E_t is the expectations operator conditional on information available in period t. Differences between the reset price and optimal prices are weighted by $(\theta\beta)^k$ because future effects of inappropriate price have lower power since the reset price will not persist for a long time. Infinite future is regarded as soon as we do not know the length of the period during the price remains unchanged.

The derivation of the loss function leads to the first order condition for the optimal reset price z_t^*:

$$2\sum_{k=0}^{\infty} (\theta\beta)^k E_t(z_t^* - p_{t+k}^*) = 0$$

[4]The derivation is presented in Appendix A.

[5]Lower case letters' variables always stand for a percent deviation from their capital letters' zero inflation steady state.

If z_t^* is separated out from p_t^*, this implies

$$z_t^* \sum_{k=0}^{\infty} (\theta\beta)^k = \sum_{k=0}^{\infty} (\theta\beta)^k E_t p_{t+k}^*$$

where

$$\sum_{k=0}^{\infty} (\theta\beta)^k = \frac{1}{1-\theta\beta}$$

Thus, firms determine their optimal reset price as

$$z_t^* = (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t\{p_{t+k}^*\} \tag{3.4}$$

where we consider the optimal price p_t^* to be the fixed markup over deviation of the nominal marginal cost from the steady state

$$p_t^* = \mu + mc_t$$

Then we get

$$z_t^* = (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t\{\mu + mc_{t+k}\} \tag{3.5}$$

This implies, the optimal reset price is weighted average of the markup over the future marginal cost. If $\theta = 0$, what means no price rigidities, then $z_t^* = \mu + mc_t$. In this case, firms do not need to take into account future, because they are able to change their price every period. Future becomes relevant only when there is a price rigidity ($\theta > 0$).

3.1.3 The Derivation of the New Keynesian Phillips Curve

In previous sections we have described basic assumptions that create baseline for the derivation of the behaviour of aggregate price inflation in Calvo economy. Now we are able to derive the New Keynesian Phillips Curve (see Whelan (2005)).

We start from the solution of the first-order stochastic difference equation

$$y_t = ax_t + bE_t y_{t+1} \tag{3.6}$$

that is obtained by stepwise substitution of $E_t y_{t+k}$ for $k > 0$ and is equal to

$$y_t = a \sum_{k=0}^{\infty} b^k E_t x_{t+k}$$

Examining this equation we can see that the expression (3.5) is the solution of the first-order stochastic difference equation, where $a = 1 - \theta\beta$, $b = \theta\beta$, $y_t = z_t^*$ and $x_t = \mu + mc_t$. Then naturally, the optimal reset price z_t^* must obey this first-order stochastic difference equation

$$z_t^* = \theta\beta E_t z_{t+1}^* + (1 - \theta\beta)(\mu + mc_t) \tag{3.7}$$

Further, from (3.3) the term z_t^* can be expressed

$$z_t^* = \frac{1}{1-\theta}(p_t - \theta p_{t-1}) \tag{3.8}$$

By substituting (3.8) into (3.7) we obtain

$$\frac{1}{1-\theta}(p_t - \theta p_{t-1}) = \frac{\theta\beta}{1-\theta}(E_t p_{t+1} - \theta p_t) + (1 - \theta\beta)(\mu + mc_t)$$

what can be treated in the following way:

$$\begin{aligned}
\frac{1}{1-\theta}(p_t - p_{t-1} + p_{t-1} - \theta p_{t-1}) &= \frac{\theta\beta}{1-\theta}(E_t p_{t+1} - p_t + p_t - \theta p_t) + (1 - \theta\beta)(\mu + mc_t) \\
\frac{1}{1-\theta}(p_t - p_{t-1}) + p_{t-1} &= \frac{\theta\beta}{1-\theta}(E_t p_{t+1} - p_t) + \theta\beta p_t + (1 - \theta\beta)(\mu + mc_t) \\
\frac{1}{1-\theta}(p_t - p_{t-1}) + p_{t-1} - p_t &= \frac{\theta\beta}{1-\theta}(E_t p_{t+1} - p_t) + \theta\beta p_t - p_t + (1 - \theta\beta)(\mu + mc_t) \\
\frac{1}{1-\theta}(p_t - p_{t-1}) - (p_t - p_{t-1}) &= \frac{\theta\beta}{1-\theta}(E_t p_{t+1} - p_t) - (1 - \theta\beta)p_t + (1 - \theta\beta)(\mu + mc_t) \\
\frac{\theta}{1-\theta}(p_t - p_{t-1}) &= \frac{\theta\beta}{1-\theta}(E_t p_{t+1} - p_t) + (1 - \theta\beta)(\mu + mc_t - p_t)
\end{aligned}$$

Multiplying by $\frac{1-\theta}{\theta}$ and replacing term $(p_t - p_{t-1})$ by inflation π_t yields

$$\pi_t = \beta E_t \pi_{t+1} + \lambda(\mu + mc_t - p_t) \tag{3.9}$$

where $\lambda = \frac{(1-\theta)(1-\theta\beta)}{\theta}$. According to (3.9) the current inflation π_t is the function of expected inflation $E_t\pi_{t+1}$ and the gap between the optimal price level $\mu + mc_t$ and the current price level p_t. We consider the term $\mu + mc_t - p_t$ to be equal to the real marginal cost mc_t^r.

Thus, the *New Keynesian Phillips Curve (NKPC)* takes form

$$\pi_t = \beta E_t \pi_{t+1} + \lambda mc_t^r \tag{3.10}$$

with $\lambda = \frac{(1-\theta)(1-\theta\beta)}{\theta}$.

It can be noticed that coefficient λ depends negatively on θ and β. Then, the higher θ is, the less sensitive inflation is according to the value of the real marginal cost. And if $\theta = 1$ what means absolute price rigidities then $\lambda = 0$ and

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

So, current inflation is determined only by the expected inflation for the next period multiplied by subjective discount factor.

Regarding the *NKPC*, Fuhrer (1997) suggested that the pure forward-looking specification of prices is empirically unimportant in explaining inflation behaviour. He proposed to improve forward-looking model upon the backward-looking price specification. In the next section we will introduce the backward-looking behaviour to the New Keynesian Phillips Curve to capture the inertia in inflation dynamics.

3.2 The New Hybrid Keynesian Phillips Curve

3.2.1 Theoretical Formulation

A high degree of persistence is an inherited feature of inflation. It is based not only on the rational expectations but also on the persistence of the agents' behaviour on the market. Agents use past information often in addition to the expectation formation. For this reason instead of one type of the firm in the Section 3.1, we consider two types of firms co-exist with different strategies of the price policy as it is proposed in Galí (1999). While the first type behaves analogous to *Calvo pricing*, the second type uses the backward-looking *rule of thumb* for the price setting. At the same time we still assume $(1-\theta)$ to be a random fraction of firms that are going to adjust their price in any given period.

Thus, according to the previous section, the aggregate price level is equal to

$$p_t = \theta p_{t-1} + (1-\theta) z_t^* \tag{3.11}$$

where z_t^* is the optimal reset price settled for period t.

Since we have two types of firms, let $(1-\omega)$ be the fraction of firms which we consider as forward-looking and p_t^f denotes the price determined by the forward-looking firm at the time t.[6] Then ω is the fraction of backward-looking firms and p_t^b is the price set by the backward-looking firm at the time t. Consequently the optimal reset price is the convex combination of forward-looking and backward-looking behaviour:[7]

$$z_t^* = (1-\omega) p_t^f + \omega p_t^b \tag{3.12}$$

We also assume that $(1-\omega)$ of forward-looking and ω of backward-looking subjects on the market form $(1-\theta)$-part of the market (regardless of the value) as well as the distribution of the whole market.

As we mentioned above, the forward looking fraction of firms behaves exactly as in the baseline Calvo model. Therefore, p_t^f may be written in the following way

$$p_t^f = (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t\{\mu + mc_{t+k}\} \tag{3.13}$$

The Equation (3.13) is the solution of first-order stochastic difference equation (3.6) with $a = 1-\theta\beta$, $b = \theta\beta$, $y_t = p_t^f$ and $x_t = \mu + mc_t$:

$$p_t^f = \theta\beta E_t p_{t+1}^f + (1-\theta\beta)(\mu + mc_t) \tag{3.14}$$

[6] Coefficient ω is from the interval $(0,1)$.

[7] It can be noticed that the derivation of this equation is based on the same principles as the derivation of the Equation (3.3).

Further, concerning the backward looking behaviour, p_t^b is given according to a *rule of thumb* as a sum of the optimal reset price from the previous period and a correction of lagged inflation (used to forecast current inflation):

$$p_t^b = z_{t-1}^* + \pi_{t-1} \tag{3.15}$$

A rule of thumb has three important features according to Galí (1999):

- in a steady state equilibrium the rule is consistent with optimal behaviour, i.e. $p_t^b = z_{t-1}^*$.
- the price settled by this rule depends only on a past information (information dated $t-1$ or earlier).
- this rule includes the future information, since the optimal reset price from the previous period z_{t-1}^* is partly given also by forward-looking firms that set their prices as infinite sums of a markup over the expected nominal marginal cost. But this feature is valid only in the case of small fraction of backward-looking firms.

Combining previous equations we are able to derive the *The New Hybrid Keynesian Phillips Curve (NHKPC)*:[8]

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda mc_t^r \tag{3.16}$$

where

$$\begin{aligned}\gamma_f &\equiv \theta\beta\phi^{-1}\\ \gamma_b &\equiv \omega\phi^{-1}\\ \lambda &\equiv (1-\beta\theta)(1-\omega)(1-\theta)\phi^{-1}\end{aligned}$$

with $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$.

All the coefficients of the *NHKPC* are functions of three model parameters: θ, ω and β. As well as in the previous section, higher measure of price stickiness θ reduces the sensitivity of inflation on the real marginal cost. The *NHKPC* has also other interesting features:

[8] Entire procedure is presented in Appendix B.

- if there is no price rigidity on the market ($\theta = 0$), then

$$\pi_t - \pi_{t-1} = \frac{1-\omega}{\omega} mc_t^r$$

  Thus, the growth of the inflation rate depends on the change of real marginal cost's percent deviation from the steady state multiplied by the ratio of the forward-looking fraction and the backward-looking fraction of the firms.

- if all firms are forward-looking ($\omega = 0$), the *NHKPC* converges to the *NKPC* introduced in the previous section.

- if subjective discount factor $\beta = 1$, then $\gamma_f + \gamma_b = 1$.

3.2.2 The Approximation of the Real Marginal Cost

The *NKPC* and the *NHKPC* can not be directly estimated due to the missing data on the real marginal cost. National accounts data do not contain the information about the cost of additional unit of output. In the literature, there are generally described two approaches where the real marginal cost is replaced by an appropriate proxy variable. We introduce these approaches only for the *NHKPC* because the derivation would be the same for the *NKPC*.

The Approximation by the Output Gap

The real marginal cost is generally known to be cyclical variable similarly like prices. Once when output is higher than its potential level, there is more competition for available factors of intermediate consumption and consequently the real marginal cost increases.[9] Written in the algebraic language

$$mc_t^r = \kappa x_t$$

[9] Galí et al. (1999) emphasize that relation between the real marginal cost and the output gap is proportional as soon as the standard sticky price framework without variable capital is taken into account. Otherwise this relation remains very close to proportional.

where output elasticity κ is a positive constant and x_t is the output gap defined as the difference between the log of real output y_t and the log of the natural or potential level of output y_t^*:

$$x_t = y_t - y_t^* \tag{3.17}$$

Then the *NHKPC* can be rewritten as

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda \kappa x_t \tag{3.18}$$

Disadvantage of this approach lies in the possible systematic bias of the error arisen during the computation of the potential level of output (see Štekláčová (2003)).

The Approximation by Real Unit Labour Costs

In the second *econometric* approach we assume the Cobb-Douglas production technology. Thus, the output is given by

$$Y_t = A_t K_t^{\alpha_k} N_t^{\alpha_n} \tag{3.19}$$

where A_t is the technology, K_t is the amount of capital, N_t amount of labor force and α_k and α_n denote shares of production factors on total output.

The real marginal cost is defined by the ratio of the wage rate to the marginal product of labor:

$$MC_t^r = \frac{W_t}{P_t} \frac{1}{\frac{\partial Y_t}{\partial N_t}} \tag{3.20}$$

Taking first derivation of (3.19) according to N_t, we obtain

$$MC_t^r = \frac{1}{\alpha_n} \frac{W_t N_t}{P_t Y_t} = \frac{S_t}{\alpha_n} \tag{3.21}$$

where S_t is the labor income share or equivalently real unit labour costs.

Consequently, lower case letters stand for a percent deviation from the steady state that takes the following form in our approach

$$mc_t^r = log(MC_t^r) - E[log(MC_t^r)] = log\left(\frac{S_t}{\alpha_n}\right) - E\left[log\left(\frac{S_t}{\alpha_n}\right)\right] = s_t \tag{3.22}$$

Now we are able to rewrite *NHKPC* as follows

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda s_t \tag{3.23}$$

Galí et al. (1999) prefer the second approach since the output gap approach has the negative sing of coefficient λ or is insignificant in their estimates. We provide detailed outline of the literature in the next chapter.

Chapter 4

Review of Literature on the New (Hybrid) Keynesian Phillips Curve

The New (Hybrid) Keynesian Phillips Curve has recently become an important part of monetary policy models.[1] The recent literature dealing with the *NKPC* and its hybrid case is built largely on the work of Fischer (1977), Taylor (1980) and Calvo (1983). It is based on the concept of sticky prices and price setting decision of forward-looking and backward-looking subjects on the market. Since new settled prices depend also on some measures of real activity, aggregating leads to the relation which is in the spirit of traditional Phillips Curve. In the following paragraphs we conclude recent major results affecting the New (Hybrid) Keynesian Phillips Curve.

First of all, we would like to mention Galí et al.(1999) since this working paper creates baseline for our master thesis and pioneered an approach to estimation of *NHKPC*. They derive and estimate equations with assumption that expectations are rational. They use quarterly data from 1960 to 1997

[1] The term New (Hybrid) Keynesian Phillips Curve stands for the New Keynesian Phillips Curve as well as for its hybrid case, since the process of their evolution has been more or less parallel during the last years.

for the U.S. The results support the presence of backward-looking behaviour and use of real unit labour costs (RULC) as a proxy for the real marginal cost. They found this indicator to be the best measure of real activity and important determinant of inflation with coefficient around 0.03. On the other hand, the output gap[2] as a measure of real activity fails yielding usually a negative sign and/or being insignificant:

> Our analysis of data suggests that movements in our measure of the real marginal cost tend to lag movements in output, in direct contrast to the identifying assumptions that imply a co-incident movement.

They also suggest the forward-looking behaviour to be very important with coefficient around 0.7, while the backward-looking behaviour is statistically significant with limited quantitative importance. The average time prices remain fixed or so called price rigidity is between one and two years. Galí et al. (1999) also discuss whether the potential source of inflation inertia is not only backward-looking behaviour but also the sluggish adjustment of the real marginal cost to movements in output.

In the further paper Galí et al. (2001) provide evidence on the fit of the *NKPC* and the *NHKPC* for the Euro area over the period 1970-1998. They relax the assumption that firms face identical constant marginal costs and they compare the characteristics of European inflation dynamics with those observed in the U.S. The *NHKPC* seems to fit Euro area data possibly better and has stronger forward-looking component than in the U.S. They also prefer "marginal costs-based" version:

> A virtue of the real marginal cost measure, which in our analysis corresponds to real unit labour costs, is that it directly accounts for the influence of both productivity and wage pressures on inflation.

[2]Galí et al. use quadratically detrended GDP.

The results of the estimation with the real marginal cost as well as for the U.S. support the strength of the forward-looking behaviour in comparison with the backward-looking behaviour. The coefficient is between $0.7-0.8$ depending upon different assumptions. As with the U.S., sluggish movement in the marginal cost appears to be an important factor accounting for observed high degree of inflation persistence.

These papers raised a lot of discussion led mainly by Rudd and Whelan (RW, 2005) and Linde (2005). They have suggested that results of previous papers are the product of specification bias or suspect estimation methods. Galí et al. (2005) argue against most of these claims and they show, their estimates are robust to a variety of different econometric procedures, including GMM estimation of the closed form as suggested by RW and nonlinear instrumental variables in the spirit of Lindé's analysis. Their results are very similar to results obtained by GMM estimation and alternative econometric approaches, including maximum likelihood procedures. They also summarize work by authors who obtained similar estimates using alternative econometric approaches (e.g. see Sbordone (2005)).

Sbordone (2005) discusses the two-step estimation procedure and presents some additional results on the estimation of the New Keynesian Phillips Curve and its hybrid case. Her results are consistent with the estimates obtained by Galí et al. (1999) and support their claims in Galí et al. (2005).

All previous authors preferred real unit labour costs as a proxy variable for the real marginal cost. Neiss et al. (2002) provide evidence that the output gap proxy interpretation of the *NKPC* deserves reconsideration. They point out potential interpretations of output gap's failure and introduce some useful solutions. At first, they emphasize labour market friction as the source of output gap's problem:

> According to New Keynesian models, a simple structural relationship between inflation and the output gap does not hold in general - it holds only if the labour market is perfectly competitive. If the labor market is not competitive, labour frictions become crucial.

Secondly, they stress difficulties in measuring the output gap and use a dynamic stochastic general equilibrium model to obtain potential output gap series. Then the output gap coefficient is positive and significant with value around $0.1 - 0.2$.

From the very recent papers, we mention Paloviita (2006). Her attitude is different from others, since she relaxes the rational expectations hypothesis ($E_t\pi_{t+1} = \pi_{t+1}$) and uses directly measured expectations i.e. OECD forecasts. Thus she allows possible non-rationality in expectations. And also in this approach output gap seems to be an appropriate proxy of the real marginal cost with coefficient around 0.2. Since directly measured expectations are not available for countries we estimate (Slovak Republic, Czech Republic, Poland and Hungary), we can not repeat this procedure and compare results.

We concentrate on the estimation of the *NKPC* and the *NHKPC* by Galí et al. (1999) concerning the output gap and real unit labour costs as a proxy of the real marginal cost variable.

Chapter 5

Generalized Method of Moments

5.1 The Introduction to GMM

This chapter explores the method for parameter estimation known as generalized method of moments (GMM).[1] It was developed by Lars Peter Hansen (1982) and has become one of the main statistical tools for the analysis of economic and financial data. The GMM estimator belongs to a class of estimators known as M-estimators that are defined by minimizing some criterion function.

The starting point of GMM estimation is a theoretical relation that the parameters should satisfy. The idea is to choose the parameter estimates so that the theoretical relation is satisfied as "closely" as possible. It is replaced by its sample counterpart and the estimates are chosen to minimize the weighted distance between the theoretical and actual values. GMM is a robust estimator in that, unlike maximum likelihood estimation, it does not require the information of the exact distribution of the disturbances. In fact, many common estimators in econometrics can be considered as special cases of GMM (e.g. the least squares estimator can be viewed as a GMM estimator, based upon the conditions that each of the right-hand side variables is uncorrelated with the residual.)

[1]This chapter is written according to Hamilton (1994).

Here we introduce Hansen's mathematical formulation of estimation problem. Let w_t be an $(h \times 1)$ *strictly stationary* vector of variables that are observed at date t, let θ denote an unknown $(a \times 1)$ vector of coefficients and let $h(\theta, w_t)$ be an $(r \times 1)$ vector-valued function, $h : (\mathbb{R}^a \times \mathbb{R}^h) \to \mathbb{R}^r$. Since w_t is a random variable, so is $h(\theta, w_t)$. Let θ_0 denote the true value of θ, and suppose this true value is characterized by the property that

$$E\{h(\theta_0, w_t)\} = 0$$

The rows of this vector equation can be described as *orthogonality conditions.* Let $y_T \equiv (w'_T, w'_{T-1}, \ldots, w'_1)'$ be a $(Th \times 1)$ vector containing all the observations in a sample of size T, and let the $(r \times 1)$ vector valued function $g(\theta; y_T)$ denote the sample average of $h(\theta, w_t)$:

$$g(\theta; y_T) \equiv (1/T) \sum_{t=1}^{T} h(\theta, w_t)$$

where $g : \mathbb{R}^a \to \mathbb{R}^r$. The idea behind *GMM* is to choose θ so as to make the sample moment $g(\theta; y_T)$ as close as possible to the population moment of zero; that is the *GMM* estimator $\hat{\theta}_t$ is the value of θ that minimizes the scalar

$$\mathcal{Q}(\theta, y_T) = [g(\theta; y_T)]' W_T [g(\theta; y_T)] \tag{5.1}$$

where $\{W_T\}_{T=1}^{x}$ is a sequence of $(r \times r)$ positive definite weighting matrices which may be a function of the data y_T. Its minimization is often achieved numerically. However, it can be shown that a necessary (but not sufficient) condition to obtain an (asymptotically) efficient estimate of θ is to set W_T equal to the inverse of the covariance matrix of the sample moments $g(\theta; y_T)$.

If the number a of parameters to be estimated is the same as the number r of orthogonality conditions, then typically the objective function (5.1) will be minimized by setting

$$g(\hat{\theta}_T; y_T) = 0$$

Then the GMM estimator is the value $\hat{\theta}_T$ that satisfies these r equations. If instead there are more orthogonality conditions than parameters to estimate

$(r > a)$, then (5.1) will not hold exactly. How close the i^{th} element of $g(\hat{\theta}_T; y_T)$ is to zero depends on how much weight the i^{th} orthogonality condition is given by the weighting matrix W_T.

5.2 Instrumental Variable Estimation

For our purpose it is desirable to show the intuition behind derivation of instrumental variable estimation according to the *GMM*.

Thus, consider a linear model

$$y_t = x_t'\beta + u_t$$

where x_t is a $(k \times 1)$ vector of explanatory variables. Suppose now that some of explanatory variables are endogenous, so that $E(x_t u_t) \neq 0$. Let z_t be an $(r \times 1)$ vector of predetermined explanatory instrumental variables that are correlated with x_t but uncorrelated with u_t: $E(z_t u_t) = 0$. In other words, the true value β_0 is assumed to satisfy the r orthogonality conditions

$$E[z_t(y_t - x_t'\beta_0)] = 0 \tag{5.2}$$

This is recognized as a special case of *GMM* framework in which $w_t = (y_t, x_t', z_t')'$, $\theta = \beta$, $a = k$ and

$$h(\theta, w_t) = z_t(y_t - x_t'\beta)$$

Suppose that the number of parameters to be estimated equals the number of orthogonality conditions $(a = k = r)$. Then the model is just identified and the GMM estimator satisfies

$$0 = g(\hat{\theta}_t, y_T) = (1/T)\sum_{t=1}^{T} z_t(y_t - x_t'\hat{\beta}_T)$$

or

$$\hat{\beta}_T = \left\{\sum_{t=1}^{T} z_t x_t'\right\}\left\{\sum_{t=1}^{T} z_t y_t\right\}$$

Concerning the optimal choice of instruments, one's first thought might be that, the more othogonality conditions used, the better resulting estimates might be. But a good instrument does not only have to be uncorrelated with u_t, but must also be strongly correlated with x_t.

For a deeper and comprehensive derivation see Hamilton (1994).

5.3 Estimation by GMM in Eviews

We provide our estimates of the New Keynesian Hybrid Phillips Curve in the program Eviews. At the beginning it is necessary to specify the equation and the instrument set, what will be discussed later. Second important aspect of specifying a GMM problem is the choice of the weighting matrix W_T. Eviews uses the optimal matrix to obtain an (asymptotically) efficient estimate. The optimal matrix as it was mentioned above is the inverse matrix of the covariance matrix of the sample moments $g(\theta, y_T)$. Thus, if we select Weighting Matrix: Time series (HAC), the GMM estimates will be robust to heteroskedasticity and autocorrelation of unknown form.

5.3.1 HAC options

HAC options are additional options for determination of weighting matrix. For the HAC option, you have to specify the kernel type, the bandwidth and prewhitening.

- The Kernel Options determine the functional form of the kernel κ used to weight the autocovariances in computing the weighting matrix to be positive semidefinite. There are two possibilities: *Barlett* and *Quadratic spectral* (QS). The difference lies in a faster rate of convergence for QS that is also smooth and not truncated. While Barlett is a staircase function, QS contains sin and cos functions. Both of them depend on the bandwidth q.

- The Bandwidth Selection option determines how the weights given by the kernel change with the lags of the autocovariances in the computation of the weighting matrix. If we select Fixed bandwidth, you may either enter a number for the bandwidth or type *nw* to use *Newey and West*'s fixed bandwidth selection criterion. Newey-West fixed bandwidth is based solely on the number of observations in the sample and is given by

$$q = int(4(T/100)^{2/9})$$

where $int()$ denotes the integer part of the argument. There are also two other possibilities *Andrews* and *Variable-Newey-West*, that are based on autocorrelations in the data.

- The Prewhitening option runs a preliminary VAR(1) prior to estimation to "soak up" the correlation in the moment conditions.

5.3.2 Tests of Estimated Equations

After estimations of the New (Hybrid) Keynesian Phillips Curve we perform a number of tests to evaluate regressions:

- we begin with *Histogram-Normality Test* to test the normality of residuals. If the residuals are normally distributed, the Jarque-Bera statistic should not be significant.

- next we test the model's overidentifying restrictions. When the number of orthogonality conditions exceeds the number of parameters to be estimated, the model is overidentified. We employ *J-statistics* to determine whether the use of instrument variables is appropriate. The *J-statistic*, which is reported in Eviews, is minimized value of the objective function. Under the null hypothesis that the overidentifying restrictions are satisfied, the *J-statistic* times the number of regression observations is equal asymptotically with degrees of freedom to the number of overidentifying restrictions. Then the *p-value* expresses whether the null hypothesis is rejected or not.

- finally we perform *Correlogram Squared Residuals Test* to test autocorrelation and partial autocorrelation in residuals. After specifying the number of lags, we compute the Ljung-Box Q-statistics for the corresponding number of lags. If there is no autocorrelations and partial autocorrelations, the Q-statistics should not be significant.

Chapter 6

Description of Data Series

Our objective is to estimate the New (Hybrid) Keynesian Phillips Curve for selected new member states (Slovak Republic, Czech Republic, Poland and Hungary). In this chapter we describe variables included in estimated equations and discuss whether they are stationary or not. The reason is the assumption of the *GMM* to employ stationary time series. All time series are quarterly and they were taken from Eurostat [4], International Monetary Fund [18], International Financial Statistics [19], NBS [24], Slovstat [34] and OECD MEI [23]:

- Gross Domestic Product in terms of goods (real GDP); Index number (2000)
- Gross Domestic Product (GDP); Billions of (specified n.c. units)
- Unit labour Costs in manufacturing industry; Local currency index (2000)
- Producer Price Index PPI(WPI); Index number (2000)
- Money Market Interest Rates (1 month); Quarterly average
- Average Interest Rates from crown deposits (total deposits without REPO); Quarterly average

6.1 GDP Deflator

We use the percentage change ($t/t-4$) of the GDP deflator as the measure of the inflation level. GDP deflator is the ratio of the nominal and real product seasonally adjusted by Cenzus x12.

Another measure of the price level is consumer price index (CPI). The difference between the CPI and the GDP deflator lies in different commodity baskets that create baseline for computation of the price level. While the GDP deflator is the weighted average price of final goods produced in the economy, the CPI employs the weighted average price of goods consumers consume. Flowing from assumptions of our equation, for our purpose it is better to use the GDP deflator.[1] In Figure 6.1 we present the GDP deflator[2] among compared countries. Figure 6.2 was enclosed to show the difference between evolution of the inflation rate and the GDP deflator.

Inflation picture for Slovak Republic, Czech Republic, Poland and Hungary is very similar and can be divided into four periods (see Arratibel et al. (2001)).

- The first period is characterized by high or even hyper-inflation that was present from the beginning of the transition to around 1994. It reached the rates of 150% per year, mostly driven by liberalization of prices and difficulties of macroeconomic stabilization to transform a central planned economy into a market economy. Since prices had been administered under a central planning regime, the subsequent adjustment caused the initial high inflation rates in these countries.

- The second period that runs from around 1994 to mid-1999 was characterized by a decline of inflation rates and their volatility. It was largely due to the stabilization of macroeconomic and political framework. It

[1] During the derivation of the *NKPC* we consider inflation to be the percentage change of prices settled by firms for products they produce.

[2] We will call the percentage change of the GDP deflator simply the GDP deflator in the next lines and chapters.

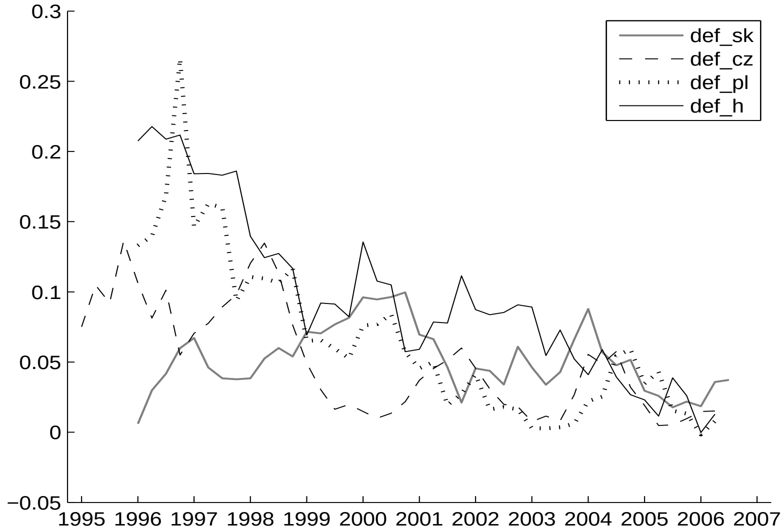

Figure 6.1: The comparison of the GDP deflator among selected countries

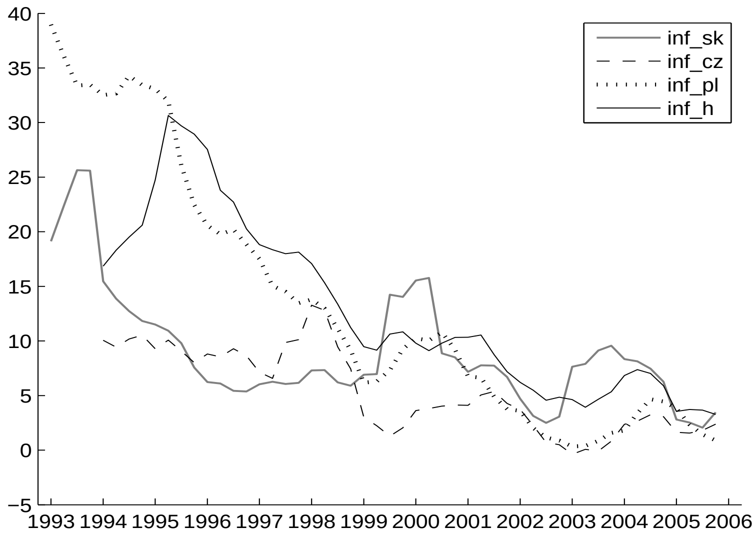

Figure 6.2: The comparison of inflation dynamics among selected countries

also took some time to fully establish central banks to be prepared to take over the control of monetary policy. But still, inflation rates remained between 10% and 30% because of transition reforms like privatisation, tax reforms, enterprise re-structuring and financial sector liberalization.

- The third period that covers mid-1999 till 2004 is characterized by a short-term increase in inflation rates due to the increase in oil prices and global slowdown. Most of special factors that influenced inflation in the first two periods vanished. Countries accepted many important reforms, were supported by foreign direct investments and became members of many European institutions.
- Finally, the most recent period began approximately with accession in the European Union in 2004. From 2005, inflation rates have been below 5%. Selected countries are preparing to accept new currency and to meet Maastricht criteria. According to them inflation rate is sustained to be lower than 1.5-percentage point + average inflation rate of the three best performing countries with the lowest inflation rate.

The impact on inflation rates had also changes in monetary regimes that took place in the Czech Republic in 1997, in Slovakia in 1998, in Poland in 2000 and in Hungary in 2001. Since selected countries have adopted direct inflation targeting as a tool for disinflation to EU rates, the overall processes of disinflation in selected countries were relatively fast and successful. The policy of direct inflation targeting has been appropriate monetary regime during disinflation and may remain appropriate until the eventual adoption of the euro (see Fidrmuc (2006)).

6.1.1 Unit Root Test

Since one of the assumptions in GMM estimation is the stationarity of time series, we employ unit root tests to test this hypothesis. We use Augmented Dickey-Fuller test (ADF), Kwiatkowski-Phillips-Schmidt-Shin test (KPSS),

	ADF		KPSS	
Country	t-Stat^A	t-Stat^B	LM-Stat^A	LM-Stat^B
Slovak Republic	−2.4259	−2.9522	0.2267	0.1590**
Czech Republic	−1.8250	−3.6664**	0.6330**	0.0882
Poland	−1.7794	−3.2840*	0.6750**	0.1747**
Hungary	−1.6946	−3.0537	0.7378**	0.1429*
	DF-GLS		PP	
Country	t-Stat^A	t-Stat^B	Adj.t-Stat^A	Adj.t-Stat^B
Slovak Republic	−1.6204*	−2.0995	−2.6545*	−3.0393
Czech Republic	−1.6665*	−3.6436**	−1.8038	−2.9710
Poland	−1.4318	−3.3459**	−1.5521	−3.4034*
Hungary	−0.0441	−2.8710	−1.6462	−2.9446

^{A} - test equation includes intercept
^{B} - test equation includes intercept and trend
* - significant at 10% level
** - significant at 5% level
*** - significant at 1% level
Lengths of employed periods - Slovak Republic: 1996q1-2006q4; Czech Republic: 1995q1-2006q2; Poland: 1996q1-2006q2; Hungary: 1996q1-2006q2.

Table 6.1: The results of unit root tests for the GDP deflator

Dickey-Fuller GLS test (DF-GLS) and Phillips-Perron test (PP) under the null hypothesis: the GDP deflator has a unit root (ADF, DF-GLS and PP test) or the GDP deflator is stationary (KPSS test). Results are reported in the Table 6.1.

We use four unit root tests in order to compare results. As we can observe from the table, results are not uniform. The main problem of the GDP deflator time series is the presence of persistence. In the case of Hungary, even if the tests do not reject that the GDP deflator is non-stationary, p-values are close to the significance level 0.1%. For other countries at least three out of four tests do not reject that the GDP deflator is stationary regarding the case (A) for Slovak Republic and the case (B) for Czech Republic and Poland.

6.2 Real Unit Labour Costs

We use real unit labour costs (RULC) as a proxy variable for the real marginal cost. Unit labour costs were divided by industrial price index in order to obtain real unit labour costs. Consequently we performed seasonal adjustment and a percent deviation from the steady state following (3.22). The comparison among selected countries can be seen on the Figure (6.3).

The value of unit labour costs (see Figure (6.4)) is the ratio of the compensation to employee and labour productivity per employee (see Kaššovicová (2006)). If unit labour costs rise, the growth of nominal wages is higher than the growth of labour productivity, purchasing power grows and demand is higher than supply. Consequently, the inflation rate rises. Otherwise the lower growth of nominal wages in comparison to the growth of labour productivity causes the growth of profits at the expense of employees. And this situation is untenable in the long term. Examining the Figure (6.4), unit labour costs of selected countries were more or less stationary since they have entered the EU.

The development of real unit labour costs is the most reliable way of assessing whether the country's competitiveness, in terms of labour costs, is improving or deteriorating. As we can notice from the Figure (6.3), the competitiveness in selected countries has improved during the last three years.

6.2.1 Unit Root Test

We proceed in the same way as in the previous section. Results are summarized in the Table 6.2.

To conclude our results, we can regard RULC of Poland as clearly nonstationary, since all four employed tests confirm it. On the other hand, RULC of Czech Republic can be considered to be stationary because in the case (B) two tests (ADF and DF-GLS) reject the null hypothesis that RULC of Czech Republic have a unit root. Finally, there is one test concerning Hungary (KPSS) and the Slovak Republic (ADF) that does not reject the

Figure 6.3: The comparison of real unit labour costs among selected countries

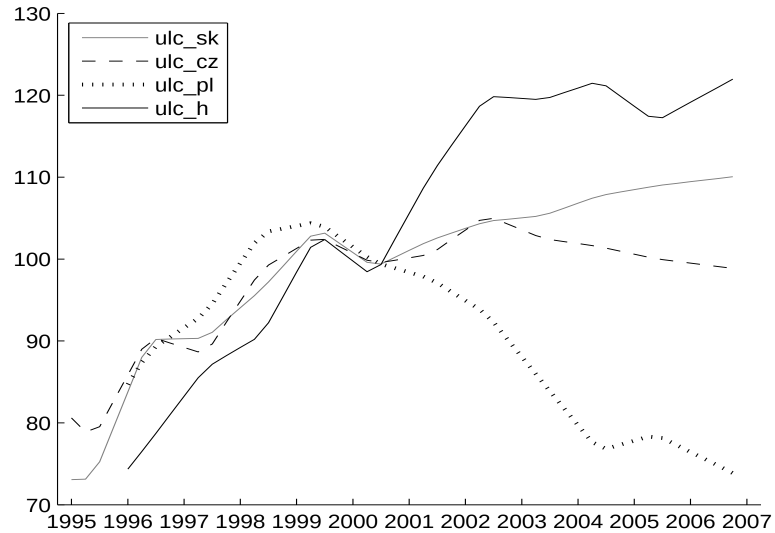

Figure 6.4: The comparison of unit labour costs among selected countries

stationarity of RULC.

Country	ADF t-Stat^A	ADF t-Stat^B	KPSS LM-Stat^A	KPSS LM-Stat^B
Slovak Republic	-0.5725	-4.0823^{**}	0.7232^{**}	0.1708^{**}
Czech Republic	0.0293	-4.2266^{***}	0.5128^{**}	0.1726^{**}
Poland	-0.2785	-2.7626	0.7943^{***}	0.1579^{**}
Hungary	-0.4068	-0.6727	0.2721	0.0975
Country	DF-GLS t-Stat^A	DF-GLS t-Stat^B	PP Adj.t-Stat^A	PP Adj.t-Stat^B
Slovak Republic	-0.7022	-2.4674	0.0633	-2.4651
Czech Republic	-0.4993	-3.7480^{**}	-0.4956	-1.4353
Poland	-0.0870	-2.5026	0.6243	-2.1549
Hungary	-0.4300	-1.5974	-2.0362	-2.1582

^{A} - test equation includes intercept
^{B} - test equation includes intercept and trend
* - significant at 10% level
** - significant at 5% level
*** - significant at 1% level
Lengths of employed periods - Slovak Republic: 1996q1-2006q4; Czech Republic: 1995q1-2006q2; Poland: 1996q1-2006q2; Hungary: 1996q1-2006q2.

Table 6.2: The results of unit root tests for RULC

6.3 Output Gap

As well as real unit labour costs, we also employ the output gap as a proxy variable for the real marginal cost in the *NKPC*. The output gap expresses the difference between the real and the potential level of output according to the Equation (3.17). The most simple and wide-spread way to compute the potential level of output is to apply Hodrick-Prescott filter (HP filler) on the seasonally adjusted real GDP. However, the problem of this approach consists in boundary points of time series since HP filter use the interval neighbourhood to obtain values.

The evolution of the computed output gap for single countries is displayed in the Figure 6.5. If potential GDP is higher than real GDP (period of recession) it implies that economy could produce with available sources more goods and services. On the contrary, higher real GDP (period of expansion) overburdens system and leads to higher inflation rates. The equilibrium is in the equality of real and potential product.

Given the construction of HP filter, the output gap is assumed to be stationary. Therefore we do not perform unit root tests for this variable.

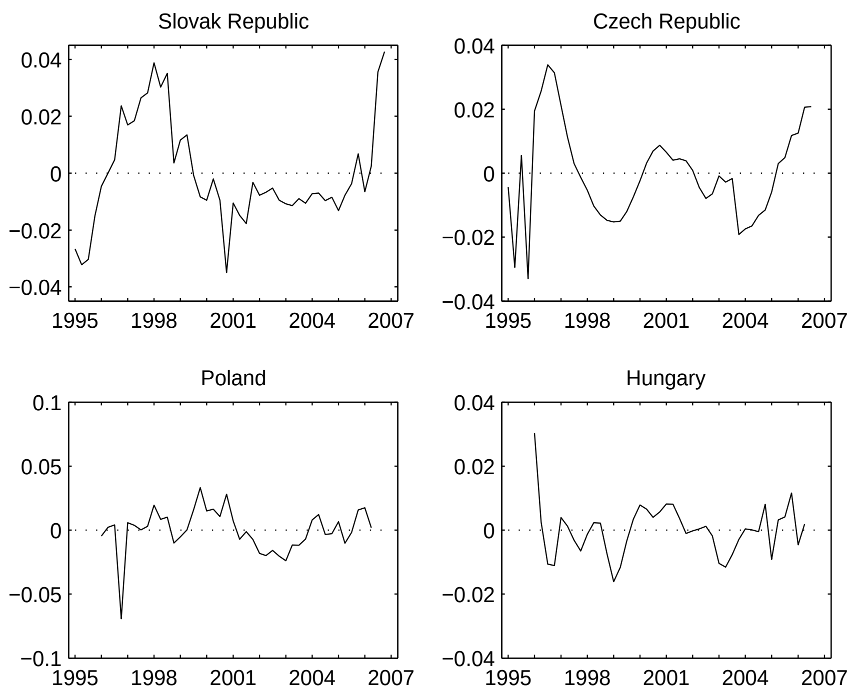

Figure 6.5: The comparison of output gaps among selected countries

6.4 Interest Rate

Instrument variable must be uncorrelated with residual and also strongly correlated with explanatory variables by GMM assumption. Galí et al. (1999) employ the interest rate as an instrument variable. Since the interest rates of selected countries are more or less positively correlated with explanatory

	deflator GDP(%)	RULC	output gap
Slovak Republic	0.4322	0.9349	0.3572
Czech republic	0.7875	0.4295	0.1515
Poland	0.7843	0.8968	0.1609
Hungary	0.8879	0.5161	0.0594

Table 6.3: The correlations of the interest rate and explanatory variables

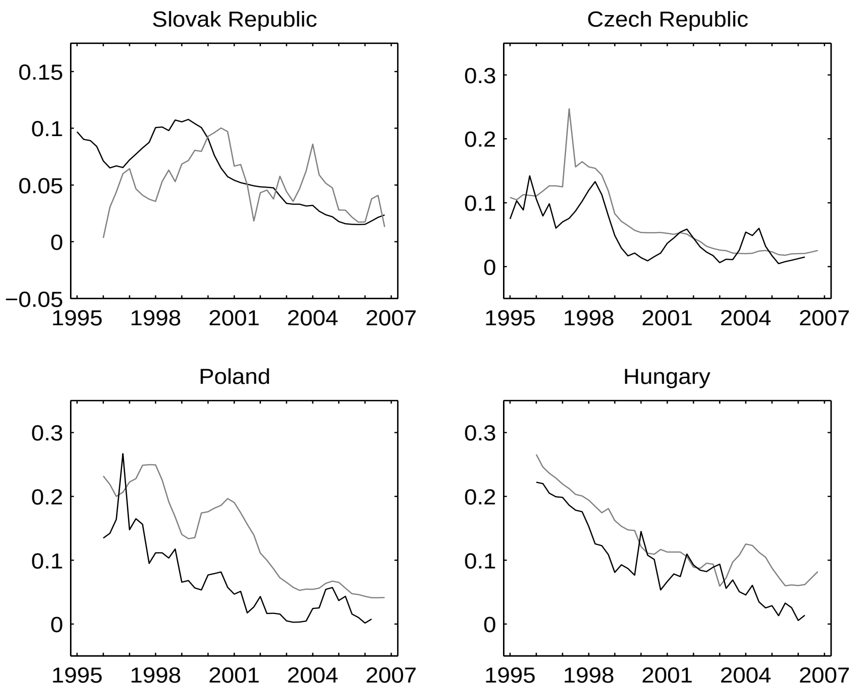

Figure 6.6: The comparison of the GDP deflator (black line) and the interest rate (grey line)

variables (see the Table 6.3 and the Figure 6.6), we included the interest rate in instrument variables in our model. We use *monthly money market interest rates* for the Czech Republic, Hungary and Poland and *average interest rates from crown deposits (total deposits without REPO)* for the Slovak Repub-

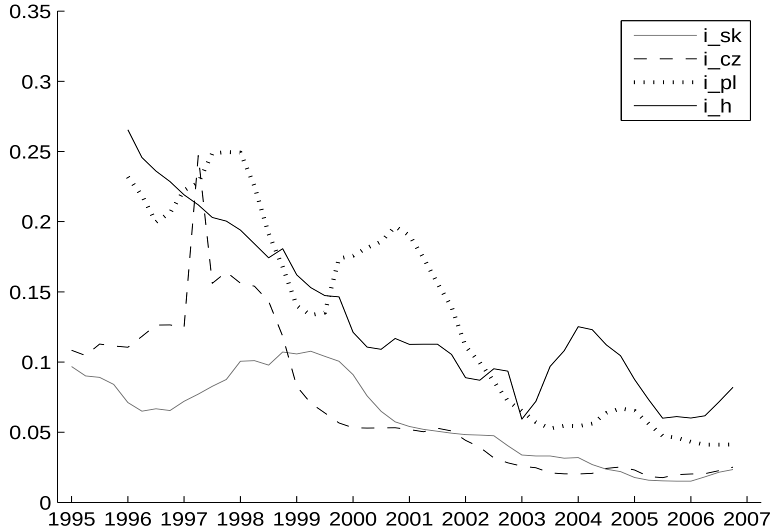

Figure 6.7: The evolution of interest rates of selected countries

lic since the former do not contain data for 1997q3.[3] The evolution of the interest rate can be seen on the Figure 6.7.[4]

6.4.1 Unit Root Test

We proceed in the same way as in previous sections and results are summarized in the Table 6.4.

The interest rates of the Slovak Republic and Hungary are clearly non-stationary because almost all tests do not reject that. Regarding the Czech republic, KPSS test does not reject that the interest rate is stationary in the case (B). Its claim is supported by DF-GLS test. So, the interest rate of the Czech republic can be taken as stationary. The interest rate of Poland as well since three tests do not reject that in the case (B).

[3]Since interest rates are highly correlated, it does not matter what type of interest rate we regard.

[4]The increase of interest rates in Czech Republic in 1997q2 was the result of currency crisis in May 1997.

Country	ADF t-Stat^A	ADF t-Stat^B	KPSS LM-Stat^A	KPSS LM-Stat^B
Slovak Republic	-1.0635	-2.1857	0.7300**	0.1254*
Czech Republic	-8.3544***	-0.7585	0.7126**	0.0919
Poland	-1.2168	-3.8942**	0.7661***	0.0624
Hungary	-2.0513	-1.9528	0.7535***	0.1903**
Country	**DF-GLS t-Stat^A**	**DF-GLS t-Stat^B**	**PP Adj.t-Stat^A**	**PP Adj.t-Stat^B**
Slovak Republic	-0.6814	-2.1941	-0.9911	-1.7641
Czech Republic	-0.5830	-5.6051***	-1.2258	-2.7706
Poland	-0.7915	-3.8440***	0.9270	-2.3741
Hungary	-0.4140	-1.6475	-2.6446*	-1.9051

^{A} - test equation includes intercept
^{B} - test equation includes intercept and trend
* - significant at 10% level
** - significant at 5% level
*** - significant at 1% level
Lengths of employed periods - Slovak Republic: 1996q1-2006q4; Czech Republic: 1995q1-2006q2; Poland: 1996q1-2006q2; Hungary: 1996q1-2006q2.

Table 6.4: The results of unit root tests for the interest rate

	deflator GDP(%)	RULC	interest rate
Slovak Republic	S^A	NonS	NonS
Czech republic	S^B	S^B	S^B
Poland	S^B	NonS	S^B
Hungary	S^B	NonS	NonS

Table 6.5: The stationarity of time series

To conclude our results: as it can be seen from the Table 6.5 we do not reject the stationarity only in time series of the Czech Republic. Other countries have at least one non-stationary variable. Non-stationarity of data set can be caused by insufficient length of time series and presence of structural changes especially at the beginning of the period. Therefore we also performed unit root tests for truncated time series (not reported here) and results encourage the use of GMM in order to estimate Keynesian Phillips Curves. Also Fidrmuc (2006) proposes, that even if some of the time series are non-stationary, the panel for selected countries is stationary.

Chapter 7

Estimation and Results

In this chapter we estimate the New Keynesian Phillips Curve and its hybrid specification. The following orthogonality conditions form the baseline for the GMM specification:

- real unit labour costs are a proxy variable for the real marginal cost

$$E_t\{(\pi_t - \beta E_t \pi_{t+1} - \lambda s_t) z_{t-1}\} = 0 \tag{7.1}$$

$$E_t\{(\pi_t - \gamma_f E_t \pi_{t+1} - \gamma_b \pi_{t-1} - \lambda s_t) z_{t-1}\} = 0 \tag{7.2}$$

- output gap is a proxy variable for the real marginal cost

$$E_t\{(\pi_t - \beta E_t \pi_{t+1} - \lambda \kappa x_t) z_{t-1}\} = 0 \tag{7.3}$$

$$E_t\{(\pi_t - \gamma_f E_t \pi_{t+1} - \gamma_b \pi_{t-1} - \lambda \kappa x_t) z_{t-1}\} = 0 \tag{7.4}$$

where z_{t-1} is a vector of instrument variables dated $t-1$ and earlier.

We assume that expectations are rational:

$$E_t \pi_{t+1} = \pi_{t+1} + \varepsilon_t$$

and we expect the disturbance term ε_t to be i.i.d. In Galí et al. (1999) it is labeled as a "cost-push" shock but e.g. Neiss et al. (2002) prefer a "price-level shock"[1]. We simply assume that ε_t is exogenous in the sense that it is not proxying for omitted dynamics or excluded endogenous variables.

We use quarterly data for the Slovak Republic over the period 1996:1-2006:4, for the Czech Republic over the period 1995:1-2006:2, for Poland over the period 1996:1-2006:2 and for Hungary over the period 1996:1-2006:2. Employed data set is specified in detail in the Chapter 6. Instrument set z_{t-1} is dated $t-1$ and earlier because if we assume the error term is uncorrelated with the past information then it is appropriate to use lagged instruments. And not all current information may be available to the public at the time they form expectations (see Galí et al. (2001)). Our vector of instrument variables involves four lags of the GDP deflator, real unit labour costs and the interest rate for model approximated by real unit labour costs. Instrument set for the model approximated by the output gap corresponds to the four lags of the GDP deflator, the output gap and the interest rate. We also add real unit labour costs to the instrument set of the *NHKPC* for the Slovak Republic and Hungary.

The Table C.1 reports what types of *HAC options* are employed in estimated equations. In all cases standard errors of estimated parameters are modified using Quadratic kernel. In some cases, prewhitening is applied and Bandwidth selection is changed. As well, baseline model estimated with $\beta > 1$ regarding *NKPC* or $\gamma_f + \gamma_b > 1$ regarding *NHKPC* was restricted to $\beta = 1$ or $\gamma_f + \gamma_b = 1$. In these specifications we do not report standard errors in parentheses for β and γ_b.

We do not estimate structural parameters as it is proposed in Galí (1999) due to our small samples. In our thesis, structural parameters are computed from estimated coefficients in the program *Excel* using the function *Solver*. Since we assume all parameters and coefficients to be positive in the derivation of the New (Hybrid) Keynesian Phillips Curve, it is not possible to

[1]They mean a shock that permanently raises the price level, but (provided that monetary policy is non-accomodative) only temporarily increases inflation by raising π_t relative to $E_t\pi_{t+1}$.

obtain structural parameters if some coefficients are estimated as negative.

The Figures C.1 and C.2 suggest that explanatory variables (real unit labour costs and output gap) can be determinants of the inflation dynamics and tend to lead the GDP deflator. Estimated coefficients and computed parameters are reported in the Tables C.2 and C.3. Overidentifying restrictions are not rejected in any case at significance 0.01% level as it can be seen in the third column of the Tables C.4 and C.5. And the comparison of actual and fitted values of the GDP deflator is displayed in the Figures C.3 and C.4.

In the next sections we present and conclude results for single countries.

7.1 Slovak Republic

Examining the *NKPC* and the *NHKPC* it is obvious that the pure forward-looking model is clearly rejected by the data. Even though all the tests do not reject the appropriateness of the *NKPC*, the coefficient of the real marginal cost is negative in both cases (1) and (2). Thus, it seems that backward-looking component is very important to capture the persistence in the inflation dynamics of the Slovak Republic. By adding the possibility to form expectations according to the backward-looking rule of thumb to the *NKPC*, we greatly improve the model. We restrict the baseline model with the output gap ($\gamma_f + \gamma_b = 1$) and then all variables are significant at the level of 0.05%. In this instance, the backward-looking behaviour is stronger than the forward-looking behaviour with coefficient γ_b to be 0.626 in the case (1) and 0.761 in the case (2). Coefficients λ and $\lambda\kappa$ are both positive and significant. The λ is equal to the 0.019, what is in line with empirical evidence. And similar estimates of the coefficient $\lambda\kappa$, that is equal to 0.221 in our work, was obtained also by Paloviita (2006) and Neiss (2002).

Regarding structural parameters, the fraction $1-\theta$ of firms that are going to adjust the price in any given period is 0.288. That implies that the prices are fixed for 3.47 quarters. The parameter $1-\omega$ is 0.161 what signifies that only one sixth of firms is forward-looking. The discount parameter β is very small with the value 0.646. It supports the claim that future is less important for price setters.

Overall, the *NHKPC* model works well in the sense of reported tests, coefficients are significant and the R^2 equals to 0.763 in the equation (1) and 0.734 in the equation (2).

7.2 Czech Republic

The estimates are in opposite to the previous estimates for the Slovak Republic. While the Slovak Republic supports the combination of the forward-looking and the backward-looking behaviour with accent on the latter, in the case of the Czech Republic the *NHKPC* entirely fails on the negative signs of real marginal cost's coefficients. It suggests that backward-looking behaviour is not present in the Czech republic and pure forward-looking model seems to be appropriate.

All coefficients of the *NKPC* are correctly signed and significant at 0.1% level. The subjective discount parameter differs among equations (1) and (2) and is equal to the 0.984 for the former and 0.849 for the latter. The coefficients λ and $\lambda\kappa$ are very similar to those obtained for the Slovak republic. The parameter θ equals to 0.899. So, prices remain fixed for 9.86 quarters what is the highest value among selected countries.[2]

The statistic tests confirm the estimates of the *NKPC* in the case (1). The second equation with output gap as a proxy variable fails on the detection of autocorrelation in residuals. We also reject the normality of residuals since the p-value is less than 0.1%. Finally, coefficients are significant and the R^2 belongs to the highest among *NKPC* estimates and is equal to 0.807 in the equation (1) and 0.721 in the equation (2).

[2]It is because the average GDP deflator of the Czech Republic is smallest among compared countries for the period 1997q1-2006q1: Slovak Republic - 5.4%; Czech Republic - 4.2%; Poland - 5.5%; Hungary - 8.7%.

7.3 Poland

Comparing the *NKPC* and the *NHKPC*, in both cases estimates reject the output gap based model. But from the Figure C.1 we can observe a coincident movement of the output gap and the GDP deflator approximately from the year 2000. The failure of the output gap based model can be caused by a structural change in data set (e.g. change in monetary regime in 2000). Therefore, we perform estimation (not reported here) for truncated time series (2000-2006) without the interest rate as an instrumental variable. The output gap coefficient is now positive and significant with the value around 0.18.

Concerning the real unit labour costs' based models, in both cases we have to restrict baseline models ($\beta = 1$ and $\gamma_f + \gamma_b = 1$). Then, the forward-looking behaviour seems to be an important determinant of inflation dynamics in Poland with coefficient γ_f to be 0.785. While in the *NKPC* the coefficient λ is equal to 0.027, by adding the lagged inflation to the model it falls to 0.018. It appears that a part of the inflation persistence was removed from the real marginal cost to the lagged inflation term.

Structural parameter θ has similar values among our models. It is equal to 0.849 in the *NKPC* and 0.843 in the *NHKPC*. Consequently, the average time prices remain fixed is 6.64 or 6.38 quarters. The portion of the backward-looking firms on the market is equal to the 0.231.

Tests on both equations confirm the appropriate specification of models, coefficients are significant and R^2 is equal to 0.811 and 0.843.

7.4 Hungary

The output gap of Hungary culminates around zero, because of approximately linear growth of real GDP. Therefore, it is not able to capture the inflation persistence and does not work in the case of the *NKPC*. On the other hand, the *NKPC* with real unit labour costs is correctly signed, but the problem is attributed in the rejection of residuals to be normally distributed.

Hybrid case of the New Keynesian Phillips Curve seems to fit data very well in both cases. Regarding the *NHKPC* with the output gap, the baseline model is restricted to $\gamma_f + \gamma_b = 1$. Then the persistence is captured by the lagged inflation and fit is improved in a comparison to the pure forward-looking model. Again, the coefficient $\lambda\kappa$ is similar to the coefficients obtained for the Slovak Republic and the Czech Republic. The coefficient λ equals to 0.061 and both of them are significant. The forward-looking character of inflation predominates with the 0.719-portion of the forward-looking subjects on the market. Prices are updated with probability 0.275 and the frequency of time adjustment is 3.63 quarters. The coefficients for expected and lagged inflation are more or less similar in both (1) and (2) cases and the portion of backward-looking firms on the market is 0.281

Tests evaluating regression do not reject the appropriateness of specified models and the values of R^2 are 0.852 and 0.868.

To testify our results, it would be very useful to perform robustness analysis of GMM estimates in the sense of sub-sample stability. But, again due to the short time series we are not able to do it. Although, the inflation history is quite heterogeneous across selected countries since they experienced the transformation to market economy, regime shift and many structural changes. But overall, the estimates indicate that inflation dynamics of new member states can be captured by the New (Hybrid) Keynesian Phillips Curve with correctly signed driving variable.

Chapter 8

Conclusion

Our intention was to estimate the New Keynesian Phillips Curve and the New Keynesian Hybrid Phillips Curve. Since the time series for expected future inflation are not available, we imposed rational expectations according to Galí et al. (1999). Models were estimated by GMM due to measurement and/or simultaneity problems. The econometric analysis of the New (Hybrid) Keynesian Phillips Curve has been limited because of already mentioned problems with short time series and different inflation levels over estimated period.

Taken as a whole, the results and implications are not uniform and do not support coincident evolution of inflation dynamics among selected countries. The results for the Slovak Republic and Hungary are quantitatively robust to the choice of driving variable if the backward-looking component is employed. Higher coefficients were obtained for the output gaps in the role of driving variable. Contrary to Galí et al. (1999, 2001, 2005) and estimates for Hungary, we suggest the backward-looking behaviour to be stronger than forward-looking component in the Slovak Republic. Since the Slovak Republic has experienced a lot of price changes, inflation expectations have possessed a complicated structure. By contrast, the Czech Republic estimates clearly do not work in the hybrid specification. Pure forward-looking specification based on real unit labour costs seems to be an appropriate determinant of inflation dynamics. Regarding Poland, we experienced problems with output gap estimation that were resolved by shortening of time series. But employing real unit labour costs did a good job in describing inflation dynamics.

We can conclude that the role of output gap as the determinant of inflation is uncertain. It seems to be an appropriate measure of the real marginal cost as well as real unit labour costs and important determinant of inflation dynamics. But it deserves a better computation as it was proposed in Neiss (2002) and further improvement of the estimation of the *NKPC* and the *NHKPC* will also be possible when longer time series are available.

But since results are very similar to those obtained for developed economies, it implies that selected countries are successfully adapting to the market economies.

Appendix A

The Standard Log-Linearization Method

Here we introduce the standard log-linearization method to derive the aggregate price level (see Fall (2000)). Assume the equation in following form

$$f(X_t, Y_t) = g(W_t)$$

where X_t, Y_t and W_t are strictly positive variables.

This equation is clearly also valid at the steady state

$$f(X, Y) = g(W) \tag{A.1}$$

The identity $X_t = e^{log(X_t)}$ and logs on both sides are used to re-write equation in the following form

$$log(f(e^{log(X_t)}, e^{log(Y_t)})) = log(g(e^{log(W_t)})) \tag{A.2}$$

The Taylor approximation of the left side for $log(X_t)$ of equation around the steady state $log(X)$ yields

$$log(f(X, Y)) + \frac{1}{f(X, Y)}[f_1(X, Y)Xx_t + f_2(X, Y)Yy_t] \tag{A.3}$$

where $x_t \equiv logX_t - logX$ and $y_t \equiv logY_t - logY$.

Similarly, the right side of equation is equal to

$$log(g(W)) + \frac{1}{g(W)}[g'(W)Ww_t] \tag{A.4}$$

where $w_t \equiv logW_t - logW$.

Equating (A.3) and (A.4) and using (A.1), yields the following expression

$$[f_1(X,Y)Xx_t + f_2(X,Y)Yy_t] \simeq [g'(W)Ww_t] \tag{A.5}$$

Now, (A.5) can be applied on the equation (3.2)

$$\left((1-\theta)(Z_t^*)^{1-\eta} + \theta = P_t P_{t-1}^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{A.6}$$

where $X_t = Z_t^*$, $Y_t = P_{t-1}$ and $W_t = P_t$. Then

$$f(Z_t^*, P_{t-1}) = \left((1-\theta)(Z_t^*)^{(1-\eta)} + \theta P_{t-1}^{(1-\eta)}\right)^{\frac{1}{1-\eta}}$$

and

$$g(P_t) = P_t$$

Following the previous procedure we derive

$$\frac{1}{1-\eta}\left((1-\theta)Z^{*(1-\eta)} + \theta P^{(1-\eta)}\right)^{\frac{\eta}{1-\eta}}[(1-\theta)(1-\eta)Z^{*-\eta}Z^* z_t^* + \theta(1-\eta)P^{-\eta}Pp_{t-1}] = Pp_t$$

$$\frac{1}{1-\eta}\left((1-\theta)Z^{*(1-\eta)} + \theta P^{(1-\eta)}\right)^{\frac{\eta}{1-\eta}}(1-\eta)[(1-\theta)Z^{*(1-\eta)}z_t^* + \theta P^{(1-\eta)}p_{t-1}] = Pp_t$$

$$P^{\eta}[(1-\theta)Z^{*(1-\eta)}z_t^* + \theta P^{(1-\eta)}p_{t-1}] = Pp_t$$

Using assumption under which $Z^* = P$ in a steady state, we obtain

$$P^{\eta}[(1-\theta)P^{(1-\eta)}z_t^* + \theta P^{(1-\eta)}p_{t-1}] = Pp_t$$

$$P^{\eta}P^{(1-\eta)}[(1-\theta)z_t^* + \theta p_{t-1}] = Pp_t$$

$$(1-\theta)z_t^* + \theta p_{t-1} = p_t$$

what is the Equation (3.3).

Appendix B

The Derivation of the New Hybrid Keynesian Phillips Curve

Combining (3.12)

$$p_t^f = \frac{1}{1-\omega}(z_t - \omega p_t^b)$$

and (3.14)

$$p_t^f = \theta\beta E_t p_{t+1}^f + (1-\theta\beta)(\mu + mc_t)$$

we get

$$\frac{1}{1-\omega}(z_t^* - \omega p_t^b) = \frac{\theta\beta}{1-\omega}E_t\{z_{t+1}^* - \omega p_{t+1}^b\} + (1-\beta\theta)(\mu + mc_t) \tag{B.1}$$

Next we can substitute (3.15)

$$p_t^b = z_{t-1}^* + \pi_{t-1}$$

to (B.1)

$$\frac{1}{1-\omega}(z_t^* - \omega(z_{t-1}^* + \pi_{t-1})) = \tag{B.2}$$

$$\frac{\theta\beta}{1-\omega}E_t\{z_{t+1}^* - \omega(z_t^* + \pi_t)\} + (1-\beta\theta)(\mu + mc_t)$$

The final step is to rewrite (3.11) as

$$z_t^* = \frac{1}{1-\theta}(p_t - \theta p_{t-1})$$

and employ it in (B.2) to complete our initial equation

$$\frac{1}{1-\omega}\left(\frac{1}{1-\theta}(p_t-\theta p_{t-1})-\omega\left(\frac{1}{1-\theta}(p_{t-1}-\theta p_{t-2})+\pi_{t-1}\right)\right)=$$
$$\frac{\theta\beta}{1-\omega}E_t\left\{\frac{1}{1-\theta}(p_{t+1}-\theta p_t)-\omega\left(\frac{1}{1-\theta}(p_t-\theta p_{t-1})+\pi_t\right)\right\}+$$
$$(1-\beta\theta)(\mu+mc_t)$$

At first p_t, p_{t-1}, θp_t and θp_{t-1} are added and subtracted and the equation is multiplied by $(1-\omega)$:

$$\frac{1}{1-\theta}(p_t-p_{t-1}+p_{t-1}-\theta p_{t-1})-\omega\left(\frac{1}{1-\theta}(p_{t-1}-\theta p_{t-1}+\theta p_{t-1}-\theta p_{t-2})+\pi_{t-1}\right)=$$
$$\theta\beta E_t\left\{\frac{1}{1-\theta}(p_{t+1}-p_t+p_t-\theta p_t)-\omega\left(\frac{1}{1-\theta}(p_t-\theta p_t+\theta p_t-\theta p_{t-1})+\pi_t\right)\right\}+$$
$$(1-\beta\theta)(1-\omega)(\mu+mc_t)$$

Subsequently, the term p_t-p_{t-1} is substituted by inflation π_t:

$$\frac{1}{1-\theta}\pi_t+p_{t-1}-\omega p_{t-1}-\frac{\omega\theta}{1-\theta}\pi_{t-1}-\omega\pi_{t-1}=$$
$$\theta\beta E_t\left\{\frac{1}{1-\theta}\pi_{t+1}+p_t-\omega p_t-\frac{\omega\theta}{1-\theta}\pi_t-\omega\pi_t\right\}+(1-\beta\theta)(1-\omega)(\mu+mc_t)$$

And then the equation is modified in the following way

$$\frac{1}{1-\theta}\pi_t+p_{t-1}-\omega p_{t-1}-\frac{\omega}{1-\theta}\pi_{t-1}=$$
$$\theta\beta E_t\left\{\frac{1}{1-\theta}\pi_{t+1}+p_t-\omega p_t-\frac{\omega}{1-\theta}\pi_t\right\}+(1-\beta\theta)(1-\omega)(\mu+mc_t)$$

$$\frac{1}{1-\theta}\pi_t+p_{t-1}-\omega p_{t-1}-\frac{\omega}{1-\theta}\pi_{t-1}=$$
$$\frac{\theta\beta}{1-\theta}E_t\pi_{t+1}+\theta\beta p_t-\theta\beta\omega p_t-\frac{\omega\theta\beta}{1-\theta}\pi_t+(1-\beta\theta)(1-\omega)(\mu+mc_t)$$

Now we add $-p_t+\omega p_t$ to the both sides of the equation and substitute the term p_t-p_{t-1} by π_t again:

$$\frac{1}{1-\theta}\pi_t+p_{t-1}-p_t+\omega p_t-\omega p_{t-1}-\frac{\omega}{1-\theta}\pi_{t-1}=$$

$$\frac{\theta\beta}{1-\theta}E_t\pi_{t+1} - p_t + \omega p_t + \theta\beta p_t - \theta\beta\omega p_t - \frac{\omega\theta\beta}{1-\theta}\pi_t + (1-\beta\theta)(1-\omega)(\mu + mc_t)$$

$$\frac{1}{1-\theta}\pi_t - \pi_t + \omega\pi_t - \frac{\omega}{1-\theta}\pi_{t-1} =$$
$$\frac{\theta\beta}{1-\theta}E_t\pi_{t+1} - \frac{\omega\theta\beta}{1-\theta}\pi_t + (1-\beta\theta)(1-\omega)(\mu + mc_t - p_t)$$

We move all terms containing π_t on the left side of the equation and all terms containing π_{t-1} on the right side of the equation:

$$\frac{1}{1-\theta}\pi_t - \pi_t + \omega\pi_t + \frac{\omega\theta\beta}{1-\theta}\pi_t =$$
$$\frac{\theta\beta}{1-\theta}E_t\pi_{t+1} + \frac{\omega}{1-\theta}\pi_{t-1} + (1-\beta\theta)(1-\omega)(\mu + mc_t - p_t)$$

$$\frac{\theta + \omega[1-\theta(1-\beta)]}{1-\theta}\pi_t =$$
$$\frac{\theta\beta}{1-\theta}E_t\pi_{t+1} + \frac{\omega}{1-\theta}\pi_{t-1} + (1-\beta\theta)(1-\omega)(\mu + mc_t - p_t)$$

Finally, we multiply the equation by $(1-\theta)$:

$$\{\theta+\omega[1-\theta(1-\beta)]\}\pi_t = \theta\beta E_t\pi_{t+1} + \omega\pi_{t-1} + (1-\beta\theta)(1-\omega)(1-\theta)(\mu + mc_t - p_t)$$

Let $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$ and write the final form of the *NHKPC*:

$$\pi_t = \gamma_f E_t\pi_{t+1} + \gamma_b\pi_{t-1} + \lambda mc_t^r$$

where

$$\gamma_f \equiv \theta\beta\phi^{-1}$$
$$\gamma_b \equiv \omega\phi^{-1}$$
$$\lambda \equiv (1-\beta\theta)(1-\omega)(1-\theta)\phi^{-1}$$

with $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$.

Appendix C

Results: Tables and Figures

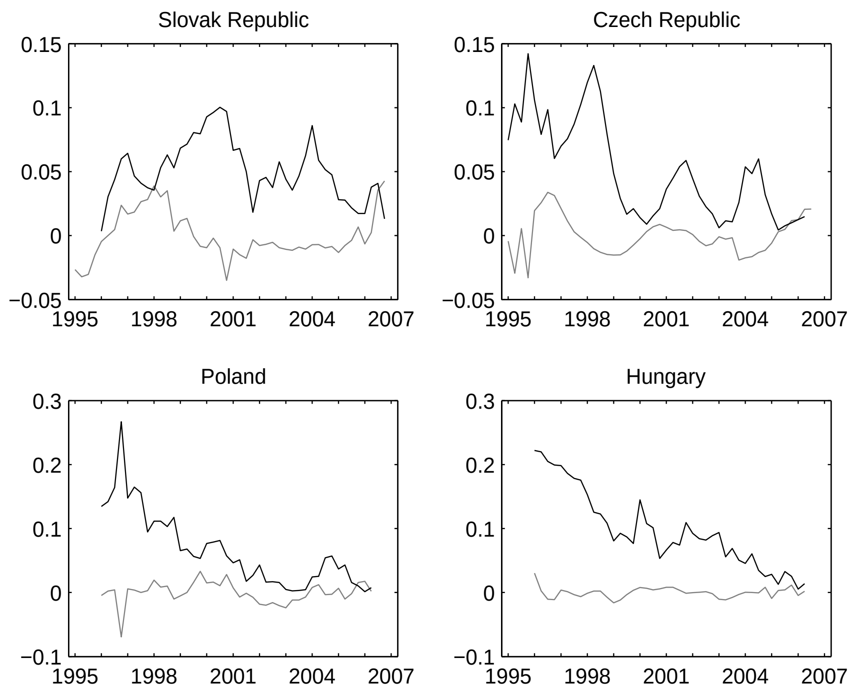

Figure C.1: The evolution of GDP deflator (black line) and the output gap (grey line)

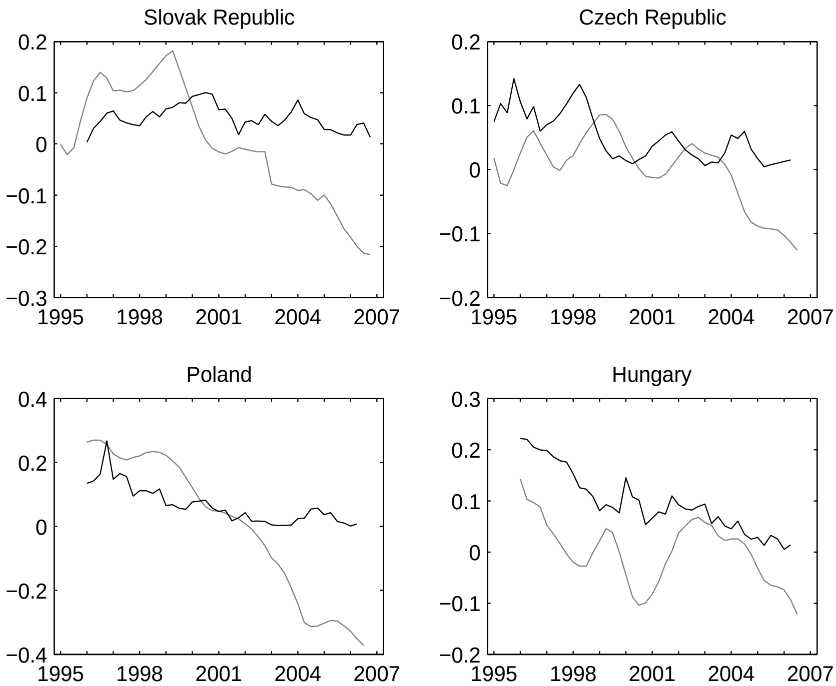

Figure C.2: The evolution of GDP deflator (black line) and real unit labour costs (grey line)

	NKPC			NHKPC		
	KO	BS	P	KO	BS	P
Slovak Republic						
(1)	QS	VNW	-	QS	NW	-
(2)	QS	NW	-	QS	NW	✓
Czech republic						
(1)	QS	NW	-	QS	NW	-
(2)	QS	NW	-	QS	NW	-
Poland						
(1)	QS	VNW	-	QS	A	✓
(2)	QS	NW	-	QS	NW	-
Hungary						
(1)	QS	A	-	QS	NW	-
(2)	QS	A	-	QS	NW	-

KO - Kernel Option; BS - Bandwidth Selection; P - Prewhitening
QS - Quadratic Spectral Kernel; NW - Newey-West Fixed Bandwidth
A - Andrews Bandwidth; VNW - Variable-Newey-West Bandwidth

Table C.1: HAC options

	$\lambda/\lambda\kappa$	β	θ	D
Slovak Republic				
(1)	-0.026 (0.003)	1.000 (−)	-	-
(2)	-0.053 (0.027)	0.949 (0.002)		
Czech Republic				
(1)	0.013 (0.008)	0.984 (0.013)	0.899	9.86
(2)	0.226 (0.041)	0.849 (0.004)		
Poland				
(1)	0.027 (0.001)	1.000 (−)	0.849	6.64
(2)	-0.173 (0.028)	1.000 (−)		
Hungary				
(1)	0.076 (0.033)	1.000 (−)	0.759	4.15
(2)	-0.118 (0.439)	1.000 (−)		

(1) - real marginal cost defined as real unit labour costs (λ)
(2) - real marginal cost defined as the output gap ($\lambda\kappa$)
D - duration (the average time the price remain unchanged; (quarters)
Standard errors are reported in parentheses below the coefficient's estimates

Table C.2: The estimates of the New Keynesian Phillips Curve

	$\lambda/\lambda\kappa$	γ_f	γ_b	θ	ω	β	D
Slovak Republic							
(1)	0.019 (0.000)	0.343 (0.001)	0.626 (0.001)	0.712	0.839	0.646	3.47
(2)	0.221 (0.002)	0.239 (0.004)	0.761 (−)				
Czech Republic							
(1)	−0.033 (0.005)	0.439 (0.028)	0.515 (0.023)	-	-	-	-
(2)	−0.157 (0.010)	0.503 (0.008)	0.483 (0.009)				
Poland							
(1)	0.018 (0.006)	0.785 (0.075)	0.215 (−)	0.843	0.231	1.000	6.38
(2)	−0.074 (0.016)	0.815 (0.012)	0.185 (−)				
Hungary							
(1)	0.061 (0.003)	0.695 (0.025)	0.282 (0.022)	0.725	0.281	0.955	3.63
(2)	0.260 (0.001)	0.632 (0.000)	0.368 (−)				

(1) - real marginal cost defined as real unit labour costs (λ)
(2) - real marginal cost defined as the output gap ($\lambda\kappa$)
D - duration (the average time the price remain unchanged; (quarters)
Standard errors are reported in parentheses below the coefficient's estimates

Table C.3: The estimates of the New Hybrid Keynesian Phillips Curve

	Jarque-Bera stat.	J-statistics	Q-statistics(4)	R^2
Slovak Republic				
(1)	0.310 (0.856)	0.207 (0.623)	2.129 (0.712)	0.583
(2)	0.535 (0.765)	0.169 (0.764)	0.979 (0.913)	0.569
Czech Republic				
(1)	2.113 (0.348)	0.203 (0.598)	4.852 (0.303)	0.807
(2)	4.832 (0.089)	0.208 (0.577)	15.529 (0.004)	0.721
Poland				
(1)	3.264 (0.196)	0.214 (0.721)	1.599 (0.809)	0.811
(2)	10.850 (0.004)	0.208 (0.658)	0.972 (0.914)	0.821
Hungary				
(1)	12.146 (0.002)	0.291 (0.376)	3.268 (0.514)	0.790
(2)	13.614 (0.001)	0.329 (0.351)	2.322 (0.677)	0.802

(1) - real marginal cost defined as real unit labour costs
(2) - real marginal cost defined as the output gap
p-values are reported in parentheses

Table C.4: The results of *NKPC*'s tests

	Jarque-Bera stat.	J-statistics	Q-statistics(4)	R^2
Slovak Republic				
(1)	0.679 (0.712)	0.249 (0.374)	2.304 (0.680)	0.763
(2)	0.096 (0.953)	0.276 (0.771)	6.341 (0.175)	0.734
Czech Republic				
(1)	9.534 (0.009)	0.364 (0.638)	5.750 (0.219)	0.921
(2)	27.047 (0.000)	0.178 (0.605)	5.311 (0.257)	0.930
Poland				
(1)	0.419 (0.811)	0.297 (0.358)	1.681 (0.794)	0.843
(2)	3.081 (0.214)	0.211 (0.648)	0.723 (0.984)	0.849
Hungary				
(1)	2.248 (0.325)	0.210 (0.556)	3.702 (0.448)	0.852
(2)	1.159 (0.560)	0.243 (0.532)	6.217 (0.184)	0.868

(1) - real marginal cost defined as real unit labour costs
(2) - real marginal cost defined as the output gap
p-values are reported in parentheses

Table C.5: The results of *NHKPC*'s tests

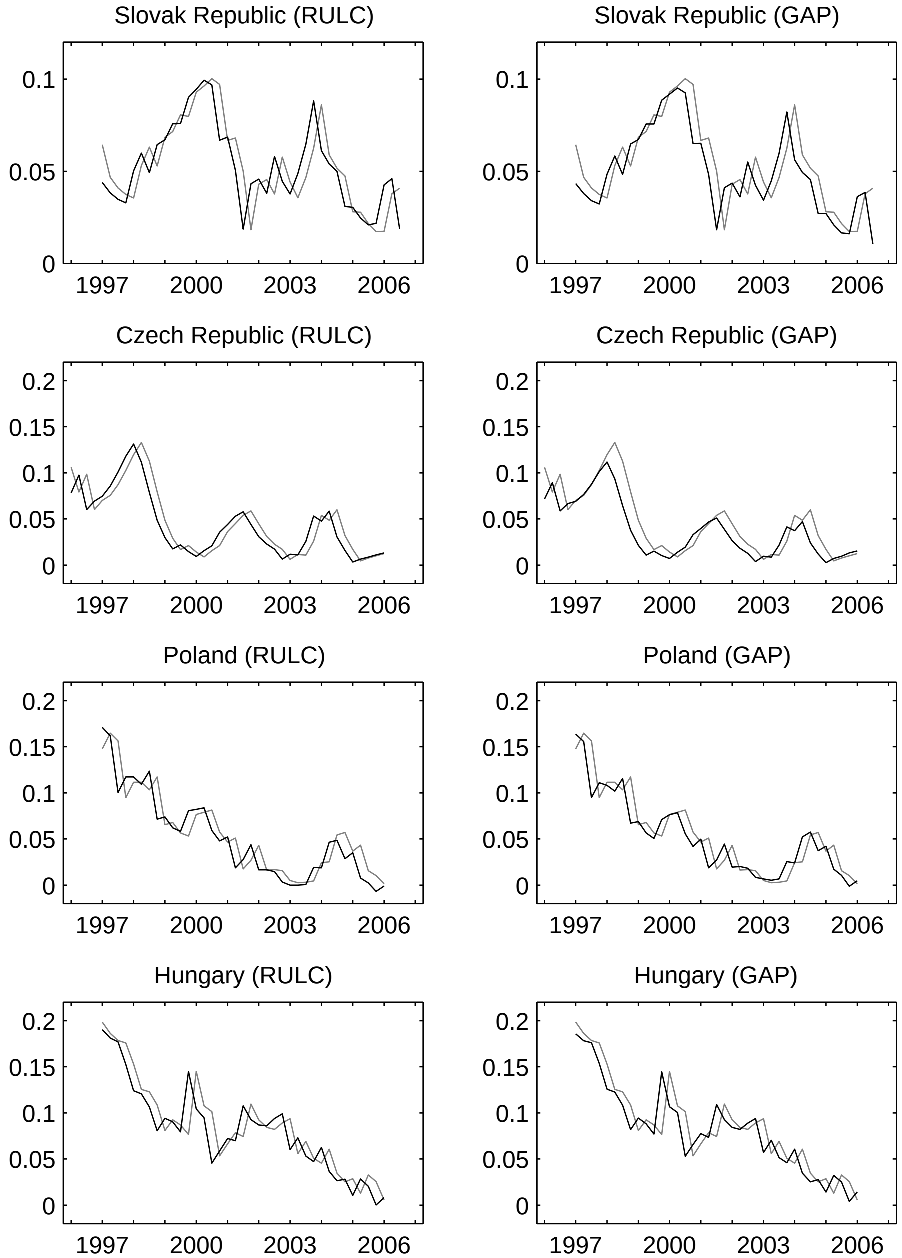

Figure C.3: *NKPC* - The comparison of the fitted GDP deflator (black line) and the actual GDP deflator (grey line)

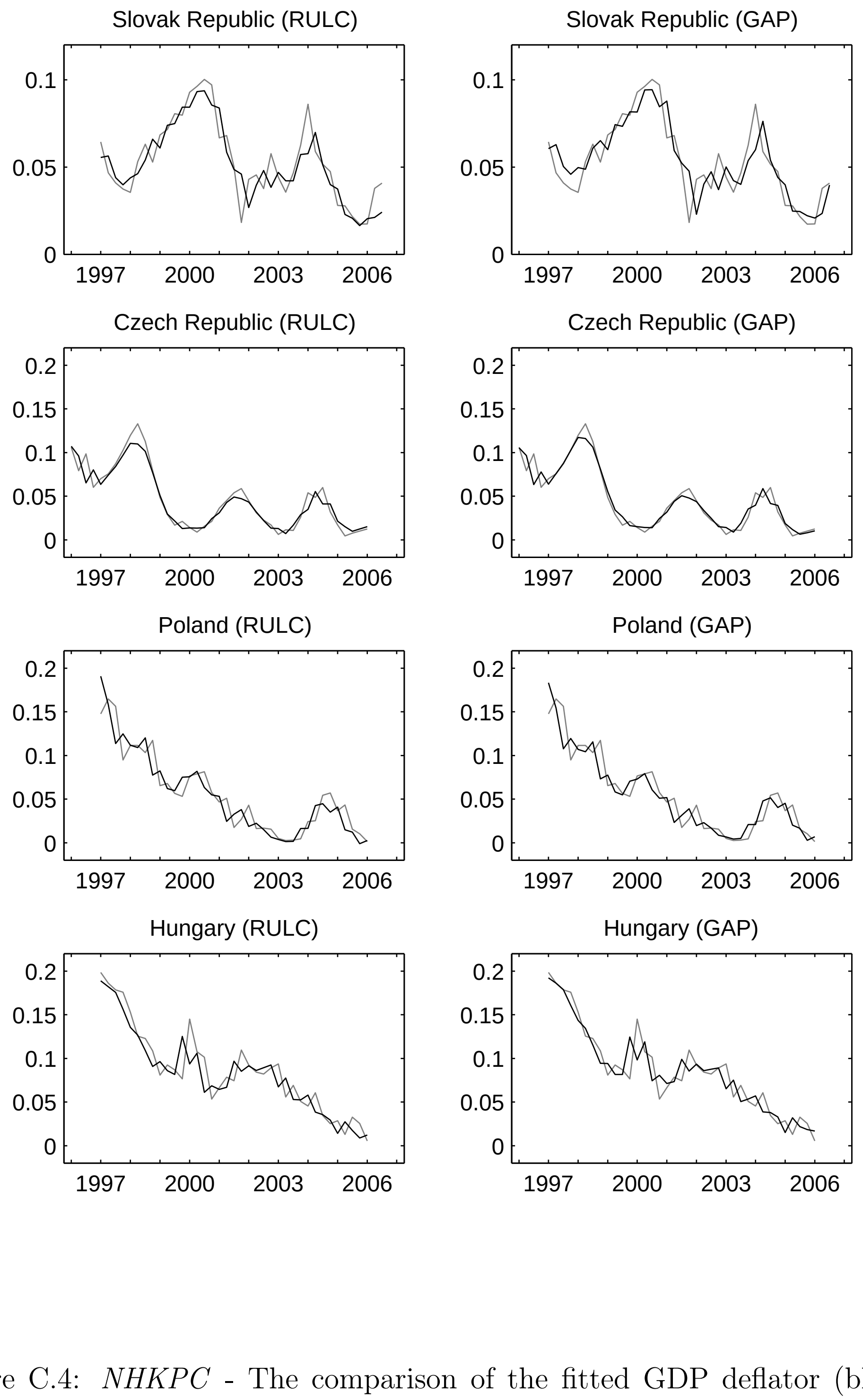

Figure C.4: *NHKPC* - The comparison of the fitted GDP deflator (black line) and the actual GDP deflator (grey line)

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