INFLATION DYNAMICS IN THE CZECH REPUBLIC: NEW EVIDENCE ON THE COST-BASED HYBRID NEW KEYNESIAN PHILLIPS CURVE

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Abstract: *New Keynesian form of the Phillips Curve assumes a short-term trade-off between inflation and real economic activity, either in unit labour cost or output gap specification. Extending the New Keynesian Phillips Curve (NKPC) with a backward-looking price setting, our aim is to examine the impact of the inflation expectations, lagged inflation, unit labour cost, import prices and real effective exchange rate on the inflation dynamics in the Czech Republic between 2000M1 and 2020M12. Dealing with non-stationary and cointegrated time series, we opted for an Error Correction Model (ECM) and an Autoregressive Distributed Lag (ARDL) model with the variables integrated of order I(1). ARDL model in differences was also compared with an ARDL model in levels. The main findings of our analysis can be summarized as follows. Firstly, our analysis indicates that the ARDL model using non-stationary time series generates spurious regression results. Secondly, the results from the ECM model and the ARDL model with first order differencing find the inflation expectations and unit labour cost statistically significant, confirming the existence of a small open economy NKPC for the Czech Republic. Thirdly, even though the backward-looking inflation setting represents a cornerstone of the hybrid NKPC, we have found no evidence for lagged inflation to have an impact on the inflation dynamics in the Czech Republic between 2000M1 and 2020M12. We thereby reject the hybrid version of the NKPC. Lastly, in spite of the Czech Republic representing a small open economy, we observed weak statistical evidence suggesting that external factors (exchange rate, import prices) influence the inflation dynamics in the Czech Republic.*

Keywords: *New Keynesian Phillips Curve, inflation expectations, real marginal cost*

JEL Classification: C32, E31, E61

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1 Introduction

Ever since Phillips (1958) first observed a negative relationship between the unemployment rate and the rate of wage inflation in data for the United Kingdom, Samuelson and Solow (1960: 192) presented the Phillips curve they coined as a "menu" for policy-makers and Phelps (1967) along with Friedman (1995) upgraded this framework with expected inflation, the Phillips curve, or the short-run trade-off between inflation and the unemployment, became a cornerstone of the modern macroeconomics. As the "original" Phillips curve seemed unable to provide a cogent explanation for chronically high inflation rates and unemployment in the 1970s, new macroeconomic approaches started to emerge, mainly the New Keynesian Phillips curve.

New Keynesianism, building mainly on the work of Fisher (1977) and Taylor (1980), emphasizes forward-looking behaviour, imperfect competition and Calvo's (1983) principle of "staggered prices". Naturally, these microeconomic foundations were incorporated into the NKPC as well, especially following the Lucas critique (Neiss and Nelson, 2005). New Keynesian authors started arguing that the inflation expectations should be swapped for lagged inflation and the Phillips curve should incorporate other proxies for real economic activity instead of the unemployment rate. The NKPC was then popularized by Roberts (1995, 2005), with follow up by Sbordone (2001, 2002), Galí and Getler (1999), Galí et al. (2001) and Galí and Monacelli (2005). Additionally, Galí et al. (1999) pioneered the estimation of the so-called "hybrid" NKPC, incorporating both forward- and backward-looking agents, trying to capture inflation persistence as well as inflation expectations. The ample empirical evidence on the hybrid NKPC confirmed the importance of incorporating both the lagged inflation as well as inflation expectations into the model (Rudd and Whellan, 2007).

Comparing the NKPC with the original Phillips curve, we are able to identify two distinct features. Firstly, New Keynesian models assume forward-looking, in case of the hybrid NKPC also backward-looking agents, where firms set prices on the bases of their expectations about the future development of cost factors. Thereby, the (hybrid) NKPC is based on inflation expectations and lagged inflation. Secondly, the NKPC shifts focus from the relationship between inflation and unemployment to the short-run trade-off between inflation and other indicators of real economic activity. The real economic activity tends to be proxied either via real marginal costs or the output gap.

Empirical evidence seems to indicate that employment of the real marginal cost delivers more satisfying results than the output gap, resulting into the general preference for the cost-based NKPC over the gap-based NKPC (Galí and Gertler, 1999). Therefore, our analysis will also be based on the cost-based hybrid NKPC.

We agree with Zobl and Ertl (2021: 672) that "the extensive empirical debate regarding the NKPC has mainly focused on advanced economies". We aim to contribute to overcoming this gap by assessing the short-run trade-off between inflation on the one hand, and inflation expectations, lagged inflation, real economic activity, import prices and real exchange rate on the other, using the cost-based hybrid NKPC on the Czech Republic as an example of a small open economy. By drawing attention to the Czech Republic, we can assess whether the NKPC is a useful tool to study the inflation dynamics in a small open EU economy outside the Eurozone. Additionally, this analysis can also provide us with information on which macroeconomic indicators drive inflation in the Czech Republic and help us conceptualize policy recommendations vis-à-vis the rising price levels amidst the Covid-19 crisis disrupting the global supply chains.

The paper is structured as follows. Firstly, we derive the cost-based hybrid NKPC equation, which will be estimated for the Czech Republic. Subsequently, we review the literature dealing with the (hybrid) NKPC in general, and then specifically in the case of the Czech Republic. Secondly, we describe the data used in the paper and provide a detailed account of our methodology and model-building. Since the time series used in this paper are mostly non-stationary, we decided to opt for ECM, and ARDL models using the first difference of the non-stationary variables. Results from the ECM and ARDL models, both in differences and levels, with regards to the cost-based hybrid NKPC in the Czech Republic between 2000M1 and 2020M12 can be found in the last part of this paper. Our results can be summarised as follows. Firstly, ARDL model in levels, when compared to the results from the ECM models and ARDL model in differences, seems to generate spurious regression. Secondly, estimations of the cost-based hybrid NKPC for the Czech Republic indicate that the inflation expectations and real economic activity proxied via unit labour cost tend to have an impact on the inflation dynamics in the Czech Republic during the analysed period, contributing to the statistical evidence of small open economy NKPC. Thirdly, both models provide limited statistical evidence of the import prices and real exchange rate influencing inflation in

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the Czech Republic, despite the Czech Republic being a small open economy. Lastly, neither of the two non-spurious models supports a backward-looking price setting, which constitutes the cornerstone of the often disputed hybrid form of the NKPC. Thereby, we reject the hybrid version of the NKPC.

2 Literature Review

In its basic cost-based form, the NKPC, stemming from the New Keynesian DSGE model,[3] is based on utility-maximizing households and profit-maximizing firms.[4] Only a fraction of firms $(1-\theta)$ has a capacity to adjust prices in period t, where θ is a measure of price-stickiness, and future developments are discounted by a factor β. Opting for the cost-based NKPC in line with Galí and Gertler (1999), the NKPC in its simplest form can be expressed as:

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

where $E_t\pi_{t+1}$ are the inflation expectations observed at time t, mc_t^r real marginal cost with $\lambda = \frac{(1-\theta)(1-\theta\beta)}{\theta}$ and ε_t is a disturbance term.[5] Fuhrer (1997) and Galí and Gertler (1999), establishing an upgraded "hybrid" form of the NKPC argue that it is also necessary to take into consideration lagged inflation on top of the forward inflation expectations. Purely forward-looking NKPC enables a costless trade-off between economic activity and inflation in their opinion, however, it tends to omit the persistence of firms' behaviour. Thus, in compliance with Galí and Getler (1999), we conceptualize the hybrid NKPC with backward-looking price setting as follows:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda mc_t^r + \varepsilon_t\ ; \tag{2}$$

where π_{t-1} represents a lagged inflation, and coefficients γ_f and γ_b are functions of structural parameters stemming from the New Keynesian model of a small economy.[6] In order to ensure linear homogeneity of inflation, the assumption $\gamma_f + \gamma_b = 1$ must hold. Also, lagged variables prevent instantaneous inflation and output adjustments to unanticipated shocks.

[3] Dynamic stochastic general equilibrium model.
[4] These firms are assumed to be in monopolistic competition, are identical apart from differenced products and pricing history and face the same constant elasticity demand.
[5] The coefficient λ depends negatively on θ and β. Thus, inflation is less sensitive to the value of real marginal cost if θ is large. In case of full price rigidity, $\theta = 1$, λ equals 0 and inflation does not depend on the real marginal costs anymore (Danišková and Fidrmuc, 2011: 3).
[6] The ability of policy-makers to have inflation under control is dependent on the relative magnitudes of these coefficients (Hornstein, 2008). Galí & Getler (1999) describe them as follows: $\gamma_f \equiv \theta\beta\varphi^{-1}$; $\gamma_b \equiv \omega\varphi^{-1}$; $\lambda \equiv (1-\beta\theta)(1-\omega)(1-\theta)\varphi^{-1}$ and $\varphi \equiv \theta + \omega[1-\theta(1-\beta)]$.

As has already been explained in the introduction, this paper focuses on the estimation of the NKPC using the case of a small open economy – the Czech Republic. The Czech Republic, not being a Eurozone member state, is however overly exposed to various external factors, namely exchange rate dynamic. External shocks, in the form of the exchange rate deviation, inevitably translate through the transmission mechanism into domestic inflation via two channels. Either directly through the import prices, or indirectly through the impact of the real exchange rate on a real economy. When added to the model, similar to Milučká (2014), the NKPC can be extended as:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda mc_t^r + im_{t-1} + REER_{t-1} + \varepsilon_t \; ; \qquad (3)$$

where $REER_{t-1}$ is a lagged impact of the real exchange rate and im_{t-1} a lagged value of import prices, assuming the linear homogeneity of inflation $\gamma_f + \gamma_b = 1$ holds. Import prices im_t are an essential determinant of a supply-side effect on inflation, especially in a small open economy (Milučká, 2014). The hybrid NKPC in this form states that the inflation rate depends on expected inflation (forward-looking component), lagged inflation (backward-looking component), real marginal cost, import prices and REER.

The literature assessing the hybrid NKPC is relatively ample. Jondeau and Le Bihan (2005) estimate the hybrid NKPP, including both backward- and forward-looking behaviour, for major European economies and the United States. They conclude that the cost-based NKPC (using real unit labour cost) model with a single lag and lead and a large forward-looking component is relevant in the US and the UK. The output-gap NKPC specification with three lags and leads and a low degree of forward-looking component, on the other hand, seems to be a better fit for continental Europe. Nason and Smith (2008) examine the hybrid NKPC using the Generalized Method of Moments (GMM) for the US, UK and Canada. They conclude that the results do not indicate evidence of forward-looking inflation dynamics in these three economies. Jean-Babtiste (2012) estimates the hybrid NKPC using survey forecasts of inflation for the United Kingdom. The author concludes that these forecasts improve estimates of the hybrid NKPC when compared to GMM or an autoregressive model. Kuester et al. (2009), on the contrary, show that the GMM approach to the NKPC leads to inconsistent and quite sizeable upward biases if cost-push shocks are persistent. Their modelling also shows that alternative estimators do not provide better results and seem to be biased as well. Roeger and Herz (2004) test the purely backward-looking Phillips curve

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and the purely forward-looking Phillips curve against a hybrid NKPC through their implications for cumulative output effects of monetary policy shocks. The authors identify a crucial difference between the backward-looking and forward looking Phillips in terms of their response to monetary shocks. They conclude that the empirical evidence on the cumulated output effects of monetary shocks is more consistent with the forward-looking model. The NKPC seems to provide the most accurate output response to a temporary interest rate innovation.

Numerous authors applied the NKPC in the context of the Czech Republic as well. One of the first were Arlt and Plašil (2005), employing a cointegration analysis of time series. The authors conclude that the NKPC model is not suitable in the conditions of the Czech Republic since it does not describe the inflation process sufficiently. Danišková and Fidrmuc (2011), employing the GMM model and a Full Information Maximum Likelihood model, estimate the hybrid New Keynesian Phillips Curve for the Czech Republic during the period from 1996 to 2009, finding out that the GMM results are likely to be more biased when the output gap is used as a proxy for real marginal costs. They also conclude that the NKPC is flatter in the Czech Republic when compared to other EU countries. Vašíček (2011) explores the inflation dynamics of the V4 countries by estimating the NKPC via the GMM framework, arguing that the output gap performs slightly better than the unit labour cost in determining the inflation rate in the short-run. All in all, the author argues that inflation seems to be mainly driven by external factors and albeit inflation holds a forward-looking component, the backward-looking component is still quite substantial. Milučká (2014) estimates parameters of the hybrid output-based NKPC model, as opposed to traditional cost-based NKPC, for the Czech Republic between 2000 and 2012 using Kalman filtration. She comes to a conclusion that the output gap has a statistically significant impact on the rate of inflation in the Czech Republic and that Czech economic agents' forward-looking behaviour predominates over backward-looking one. Also, the author finds out that Czech inflation might also be driven by the development in import prices. Baxa et al. (2015) examine the open economy NKPC with time-varying parameters and stochastic volatility using the data on three Central European countries (the Czech Republic, Hungary and Poland). By employing the Bayesian model averaging the authors document a relatively weak and barely significant relationship between inflation and the output gap. Zobl and Ertl (2021) also assess the NKPC in Central and Eastern European (CEE)

countries, including the Czech Republic. The authors offer rather convincing empirical evidence of the existence of small open economy NKPC in the region.

3 Data and methodology

In this section, we provide a detailed explanation of the data and methodology utilized in this paper. Firstly, we provide the reasoning behind the variable selection and data adjustments. Subsequently, dealing with the time series, we run tests on stationarity and cointegration. Since the time series we opted for are mostly non-stationary, we make use of the Error Correction Model and Autoregressive Distributed Lag model using the first difference of the non-stationary variables. All the calculations, data adjustments and modelling in this paper were conducted using the R programming language.

3.1 Data

The data used in this paper consists of monthly time series from 2000M1 to 2020M12 and were retrieved from the Czech National Bank (ARAD) and the Czech Statistical Office (CSZO). Each time series is transformed into logarithms and seasonally adjusted, using the x11 regression from the "X-13ARIMA-SEATS" R package. As an inflation proxy, we opted for the annualized monthly change of seasonally adjusted logged Consumer Price Index (logCPI), where 2015=100. Import prices (logIM) are proxied via a change of logged seasonally adjusted index of import prices (2015=100). As a proxy for expected inflation, we use the Czech National Bank's (CNB) monthly data from the Survey of Professional Forecasters (SPF). These data represent financial market inflation expectations for the one-year horizon (logSPF_1y). Even though the SPF often tends to be disregarded, for the most part, they were used as a proxy for inflation expectations, for instance, by Jean-Babtiste (2012), Binder (2015), Coibion and Gorodnichenko (2015) or Ball and Mazumder (2018). Mavroeidis et al. (2014) also point out the beneficial properties of survey data as a measure of inflation expectations. The logged seasonally adjusted real effective exchange rate (logREER) is defined as a monthly nominal effective exchange rate of the CZK deflated by CPI and weighted by foreign trade turnover, where 2015=100.[7] Lastly, it

[7] Same as Danišková and Fidrmuc (2011: 8), we opted for REER level, not REER gap (derived by subtracting trend REER from level REER).

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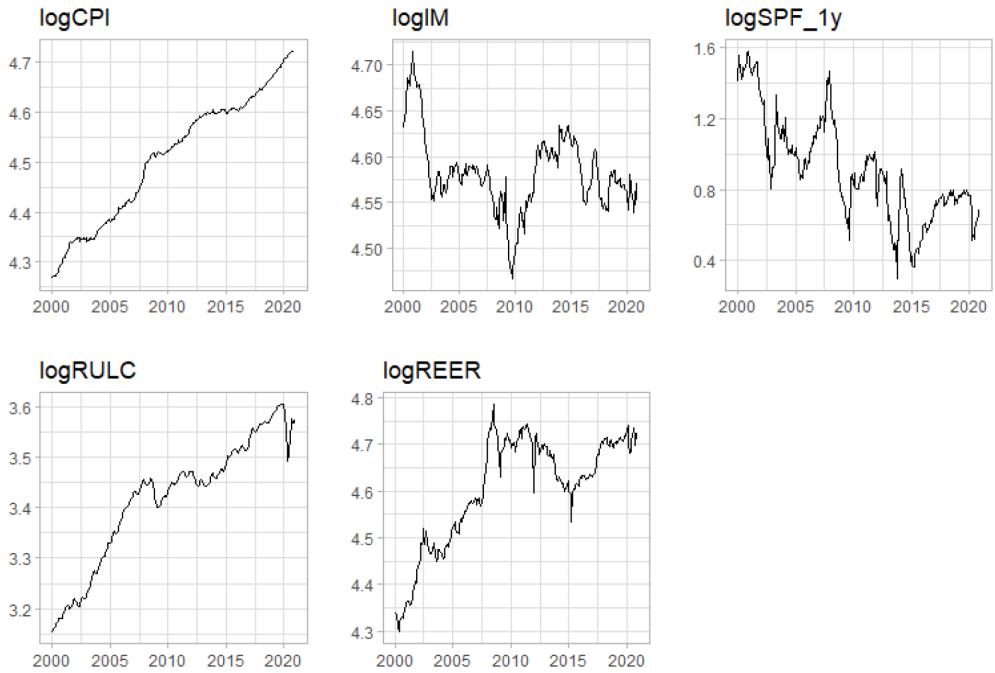
is generally known that the real marginal costs are practically unobservable. Danišková and Fidrmuc (2011), however, argue that the real marginal cost can under the assumption of the Cobb-Douglas production technology take a form of labour income share or equivalently real unit labour cost. In our model, labour costs are therefore proxied via logged and seasonally adjusted real unit labour cost (logRULC) index, defined as the ratio of compensation of employees per person employed to real labour productivity per person, where 2015=100. Since only quarterly data are available, we disaggregate them into monthly time series using Denton-Cholette method, employing "tempisagg" R package (Dagum and Cholette, 2006). All the data are displayed in Figure 1.

Figure 1: Selected monthly time series for the Czech Republic, 2000-2020



Source: Authors' elaboration based on the ARAD and CZSO data.

Since macroeconomic time series tend to be non-stationary, we compare two statistical tests for stationarity, Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Table 1).[8] One way to make

[8] There is one technical difference between the two. ADF test uses H_0: "the series has a unit root", while KPSS formulates H_0 as "the process is trend stationary". Thereby, in case of the ADF test rejecting the null hypothesis means that the time series is stationary, while in the case of the KPSS rejecting the null hypothesis means that the time series is non-stationary.

non-stationary data stationary is to correct them by differencing.[9] Employing the ndiffs function from the R "forecast" package, we estimate the number of differences needed for the non-stationary time series, and we run the tests again. The unit root tests in column (3) and (4) show us that non-stationarity subsequently disappears with the time series integrated of order 1.

Table 1: Unit-Root ADF and KPSS Tests

	ADF (1)	**KPSS** (2)	**ADF$_{diff}$** (3)	**KPSS$_{diff}$** (4)
logCPI	0.6179	0.01	0.01**	0.1**
logIM	0.4379	0.0201	0.01**	0.1**
logSPF_1Y	0.0625	0.01	0.01**	0.1**
logRULC	0.6305	0.01	0.01**	0.1**
logREER	0.6267	0.1**	0.01**	0.1**

Note:**stationary at 5% significance level. Test equations include both intercept and trend. Incorporation of adf.test and kpss.test function in "tstimes" R package.

Source: Authors' elaboration based on the ARAD and CZSO data.

Since the variables are stationary of order 1, that is $\{Y_{CPI}, X_{SPF}, X_{RULC}, X_{REER}, X_{IM}\} \sim I(1)$, we test for coordination vectors between them based on Johansen and Juselius (1990). Running the Johansen's cointegration test (Table 2), the trace and maximum eigenvalue type demonstrate that there is one cointegration relationships at 5% critical value and there exist a long-term relationship between the variables.

Table 2: Johansen's Cointegration Test

Rank	λ_{Trace}	**5% value**	$\lambda_{Max\ Eigen}$	**5% value**
r <=4	7.72	9.24	7.72	9.24
r <=3	16.34	19.96	8.62	15.67
r <=2	27.60	34.91	11.26	22.00
r <=1	51.63	53.12	24.03	28.14
r =0	113.14	76.07	61.51	34.40

Note: Using VARselect command, 5 lags were chosen as the optimal lag based on AIC (Akaike information criterion) minus 1. For the cointegration test, ca.jo() command is used from "urca" R package.

Source: Authors' elaboration based on the ARAD and CZSO data.

[9] Differencing can help stabilize the mean of a time series by removing changes in the level of a time series. A single difference means $\Delta x_t = x_t - x_{t-1}$.

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3.2 Methodology

Since the time series are multivariate - I(1) - and there exists a cointegration relationship between them (ût ~ I(0)), we can dutifully avoid spurious regression by constructing an *Error Correction Model.* The general form of an ECM is:

$$\Delta Y_t = \alpha_0 + \beta_1 \Delta X_{1,t} + \ldots + \beta_i \Delta X_{i,t} + \pi \hat{u}_{t-1} + e_t \quad (4)$$

The ECM includes both the short-run and long-run information. The β_1 (impact multiplier) represents *short-run* effect measuring the immediate impact a change in $X_{i,t}$ will have on a change in Y_t. On the other hand, π is a feedback effect,[10] and along with $\hat{u}_{t-1}$ provide information on the long-run effect. Feedback effect shows how quickly does the dependent variable return to the equilibrium once it oscillated, that is the extent to which any disequilibrium in the previous period affects any adjustment in Y_t. Lastly, $\hat{u}_{t-1}$ measures the long-run response (Asteriou and Hall, 2016). We run the ECM based on the hybrid NKPC from the equation (3).

Additionally, we compare these results with the simple *Autoregressive Distributed Lag* model using the first difference of the non-stationary variables. As was shown before in the Table 1, all the variables are integrated of order I(1).[11] The simple differenced ARDL model describing the behaviour of Y in terms of variables Xi can be subsequently formalized as follows:

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta Y_{t-2} + \ldots + \gamma_0 \Delta X_{i,t-1} + \gamma_1 \Delta X_{i,t-2} + u_t \quad (5)$$

where $u_t \sim iid(0,\sigma^2)$; and γ denotes short run reaction of Y_t to changes in $X_{i,t}$.

4 Results and Discussion

ECM and ARDL models estimating the short-run relationship between inflation and real unit labour cost for the Czech Republic during the period 2000M1-2020M12 are depicted in the Figure 2. Running the unit-root AFD and KPSS tests as well as the Johansen's cointegration test proved useful in rejecting utilization of models based on ex ante non-stationary data. High adjusted R^2 also serves as a "rule of thumb" of the regression spuriousness

[10] Also known as adjustment effect.
[11] The first order differencing might remove certain information from the data, however, it should not impede reliable interpretation of the results.

(Baumöh and Lyócsa, 2009). Taking a look at column (iii) in Figure 2, non-stationary data with simple ARDL in levels created spurious regression results falsely indicating strong relationship between lagged logCPI, logged expected inflation and logged real labour unit cost and the short-term development of inflation, as described by the general equation (3). On the other hand, neither the lagged import prices, nor the lagged real effective exchange rate seem to have an impact on the inflation development in the spurious ARDL.

Turning our attention to the ECM (i) and ARDL in differences (ii) models, we can immediately notice that both models generate relatively low multiple R^2, indicating more reliable results. Comparing the two models, the ECM shows the longer-term statistical significance of the lagged logRULC, the variable we choose to employ as a proxy for the real marginal costs. The logged RULC is statistically significant also in the ARDL model, in its differenced form, following the removal of the non-stationarity. These findings appear to be in contrast with Vašíček (2011), who claim that the real marginal cost do not belong among the main inflation-driving variables. Based on his results, evidence for real marginal cost is not unambiguous and the output gap performs statistically better in this regard. Zobl and Ertl (2021), on the other hand, found the labour share gap, used as the standard proxy for real unit labour cost, statistically significant for the Czech Republic by employing the GMM model. Results from both our models provide evidence for the logRULC driving the inflation rate for the Czech Republic.

The ECM model assigns short-term significance to the differenced expected inflation as well. Subsequently, only the lagged expected inflation and lagged RULC prevail in the longer run in terms of their impact on the inflation rate. The ARDL in differences, model with variables integrated of order *I(1)*, empirically supports both the expected inflation and the RULC as drivers of inflation dynamics in the Czech Republic. Empirically speaking, the inflation expectations seem to be a consistent finding throughout the literature with regards to the determinants of the inflation dynamics for the Czech Republic. Baxa et al. (2015: 128), for instance, argue that the decrease in inflation persistence in the Czech Republic has been accompanied by anchoring of inflation expectations and "the Czech inflation process seems to be driven mainly by its forward-looking component". Similarly, Franta and Sutóris (2020) found out that that CNB's surveys of professional forecasters evince a strong statistical significance in explaining the evolution of inflation for the Czech Republic between 1998Q1 and 2019Q4. Inflation expectations of

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financial analysts on both the trend and the cyclical component of inflation, while firm managers and the CNB expectations on just the cyclical component. Zobl and Ertl (2021: 673) also argue that "inflation expectations determine inflation dynamics strongly and statistically significantly across countries [CEE region]". Their results indicate that the expected inflation is statistically significant and stable over tome, emphasizing the importance of the CNB credible commitments to low inflation and anchoring inflation expectations.

Figure 2: ECM and ARDL results of the hybrid NKPC in the Czech Republic between 2000M1 and 2020M12

	ECM (i)	**ARDL in differences** (ii)	**ARDL in levels** (iii)
(Intercept)	-0.045 (0.036)	-0.025* (0.012)	-0.029 (0.037)
$logCPI_{t-1}$	-0.004 (0.006)	-	0.994*** (0.006)
$logSPF\_1y_{t}$	-	0.005*** (0.001)	0.004*** (0.001)
$logSPF\_1y_{t-1}$	0.005*** (0.001)	-	-
$logRULC_{t-1}$	0.0144** (0.005)	-	-
$logRULC_{t}$	-	0.019** (0.005)	0.015** (0.005)
$logIM_{t-1}$	-	-	0.002 (0.007)
$logREER_{t-1}$	-	-	-0.003 (0.004)
$logIM_{t-2}$	0.005 (0.007)	-	-
$logREER_{t-2}$	-0.002 (0.004)	-	-
$\Delta logCPI_{t-1}$	-	0.058 (0.066)	-

$\Delta logSPF\_1y_t$	-0.005* (0.002)	-0.001*** (0.003)	-
$\Delta logRULC_t$	0.024 (0.027)	0.019 (0.028)	-
$\Delta logIM_{t-1}$	0.095*** (0.022)	0.016 (0.023)	-
$\Delta log\ REER_{t-1}$	0.049*** (0.013)	0.003 (0.013)	-
Observations	242	241	245
R^2	0.263	0.177	0.9995

Note: *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively. Standard errors in parentheses. ECM model built using ecm function from the "ecm" R package, ARDL dynardl function from the "dynamic" R package.

Source: Authors' elaboration based on the ARAD and CZSO data.

Another interesting finding is that none of the models, excluding the spurious ARDL regression, provides evidence for backward-looking inflation behaviour, as preached by the hybrid NKPC. This might be due to the fact that we opted for SPF as a proxy for inflation expectations. Jean-Babtiste (2012: 813), for instance, claims that "survey-based inflation forecasts make the Phillips curve predominantly forward-looking". Still, various authors also found evidence that forward-looking behaviour is more predominant than backward-looking behaviour. Danišková and Fidrmuc (2011) observe that the forward-looking component is on average more significant than the backward-looking component in both output gap and real unit labour cost specifications of the NKPC for the Czech Republic. Examining inflation dynamics in the Czech Republic using the NKPC, Milučká (2014: 65) also concludes that "nowadays the share of forward-looking agents prevails share of backward-looking agents in the Czech Republic". Baxa et al. (2015: 123) "find evidence that the forward-looking inflation term is more important than the backwards-looking one" and although the authors argue that the backward-looking term tracking inflation persistence remains largely significant in the CEE region, the Czech Republic represents an exception among the analysed Central European countries (Baxa et al., 2015). Zobl and Ertl (2021: 681) do not observe any empirical support for the inflation persistence as well, concluding that "we reject the hybrid version of the NKPC, on the basis that survey based inflation expectations seem to encompass any backward-looking price setting". Only

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Vašíček (2011: 94) registers higher inflation persistence in the CEE region, including the Czech Republic, indicating significant backward-looking component. He argues that many firms within the post-communist region still employ simple backward-looking price setting, which is consistent with adaptive rather than rational expectations, due to the lack of credible monetary policy or a missing nominal anchor. This finding is, however, nowadays rather rare in the literature.

Lastly, the ECM finds differenced and lagged REER and import prices to have an impact on the inflation development in the Czech Republic, as suggested also by Milučká's results (2014). Vašíček (2011) also claims that, besides inflation expectations and inflation persistence, the external factors are the ones driving the inflation rates the most, especially in the context of a small and open economy similar to that of the Czech Republic. Examining the logic of the open-economy Phillips curve for the Czech Republic, Franta and Sutóris (2020) find the exchange rate and foreign prices also statistically significant. The impact of external factors (nominal depreciation of the Koruna to the Euro, the REER, import prices, commodity prices and the oil price) is non-negligible even in Zobl and Ertl's GMM model (Zobl and Ertl, 2021). These two variables, however, according to the ECM (i) model, seem to influence inflation only in the short-run in lagged and differenced form. On the other hand, neither the lagged REER nor the import prices are significant in the ECM model in the longer run. Furthermore, we observe no statistical evidence of the logREER and the logIM having an impact on the development of inflation in the ARDL model with differences. The REER is overall surprisingly unimpactful, in all three models. There might be four reasons for that. One reason can be that effects of external factors on inflation are only temporary and non-linear and are already reflected in the inflation expectations (Baxa et al., 2015). Another reason is offered by Baxa and Šestořád (2019), who argue that the rising discrepancy between the impact of the exchange rate floor on the development of inflation can be explained by a "flattened Phillips curve".[12] A similar argument was also being made for the case of Poland by Szafranek (2017). The third reason can be that the CNB decided to introduce a one-sided floor on the exchange rate as an additional monetary policy instrument in November 2013. However, it was not until the August 2015 the CNB started pursuing active foreign exchange interventions policy. Therefore, even if Caselli (2017) argues that the CNB was relatively

[12] Trend long observed in the developed Western economies indicating the dynamics of real economic activity and inflation becomes increasingly decoupled (see e.g. Krueter et al., 2009).

successful in fighting deflationary pressures via the real exchange rate, the period between the second half of 2015 and the end of 2020 is relatively short to influence the results, although the ECM indicates some trends. Lastly, Baxa and Šestořád (2019) suggest that the rising quality of the Czech exports and participation in global value chains might also play a role in the declining influence of the REER on the evolution of inflation.

5 Policy Implications and Concluding Remarks

In spite of the extensive empirical findings regarding the NKPC in advanced economies, we draw attention to example of a small open economy in our analysis. The aim of this paper was to examine the trade-off between inflation on the one hand and real economic activity on the other, utilizing the concept of the NKPC for the Czech Republic. The implicit research question in this paper was to assess whether the NKPC is a useful tool to study inflation dynamics in the Czech Republic. If so, what are the major drivers of inflation for the Czech Republic than? Since our time series were non-stationary, we relied on the Error Correction Model and Autoregressive Distributed Lag using the first difference of the non-stationary variables. The ARDL model in differences was also compared to the ARDL model in levels.

Our findings can be summarized as follows. Firstly, our analysis has some econometric implications, since running the ARDL model in levels with non-stationary time series generated obviously spurious regression results. This finding can be excerpted from the comparison of the ARDL model in differences and in levels. The precariousness of the regression based on non-stationary data is long known (Granger and Newbold, 1974; Baumöhl and Lyócsa, 2009), although it still tends to be overlooked. Even though it did not represent the primary goal of this paper, it is important to point out to potential impreciseness stemming from the regression based on non-stationary time series for the future research.

Secondly, the results from ECM model and the ARDL model with first order differencing find the inflation expectations for one-year horizon and the logRULC statistically significant, similar to the authors such as Baxa et al. (2015), Franta and Sutóris (2020) or Zobl and Ertl (2021). This finding regarding the trade-off between the inflation dynamics and the real economic activity confirms the existence of small open economy NKPC in the Czech

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Republic. In light of sustained low inflation during the period before Covid-19 pandemic, it was increasingly argued that the influence of real economic activity weakened vis-à-vis the evolution of inflation, leading to the "flattening of the Phillips curve" (Szafranek, 2017). Based on our empirical findings we cannot but agree with Zobl and Ertl (2021) who claim that it is too early to declare the NKPC obsolete, as the empirical evidence does not support a flattening of the NKPC in the small open Czech economy.

Thirdly, similar to Zobl and Ertl (2021), we can also reject the hybrid version of the NKPC on the basis that inflation expectations seem to encompass any backward-looking price setting. None of the models we employed in our paper give weight to the lagged inflation, as a proxy for backward-looking price setting, despite being one of the cornerstones of the hybrid NKPC models. These results are consistent with other findings in the field (Danišková and Fidrmuc, 2011; Jean-Babtiste, 2012; Milučká 2014; Baxa et al., 2015; Zobl and Ertl, 2021). Thus, monetary policy being conducted by the Czech authorities might be able to affect future inflation by influencing inflation expectations (forward-looking component), for instance by making a credible commitment to future policy actions. The attempts trying to tackle inflation persistence, backward-looking behaviour, would be, based on our findings, probably unimpactful. This, however, seems to be a new trend. Baxa et al. (2015), for instance, argue that the link between higher volatility of inflation and inflation persistence has only been broken recently, and the "most significant decrease in inflation persistence has been recorded in the Czech Republic, where it has been accompanied by anchoring of inflation expectations" (Baxa et al., 2015: 128).

Lastly, we observed weak statistical evidence suggesting that either the exchange rate or the import prices influence the inflation dynamics in the Czech Republic, despite representing a small open economy. This does not, however, constitute a surprising finding (Baxa et al., 2015; Baxa and Šestořád, 2019). These two variables seem to have a statistical significance based on the ECM model in the short-run in lagged and differenced form. On the other hand, neither the lagged REER nor the import prices are significant in the ECM model in the longer run. No statistical evidence of the logREER and the logIM having an impact on the development of inflation is recorded in the ARDL model with differences. As a result, monetary policies trying to steer the exchange rate in order to influence the inflation rate, such as the CNB's exchange rate commitment launched in November 2013 (lasting until April

2017), should not be relied upon by the Czech monetary authorities in the medium and long-run, at least based on our findings.

This paper is structured as follows. Firstly, following the introduction into the Phillips curve in the beginning of our paper, in the first chapter we derived the cost-based hybrid NKPC equation and reviewed the literature concerning the NKPC in general and also specifically in the case of the Czech Republic. Secondly, we described the data and methodology utilized to estimate the hybrid NKPC for the Czech Republic between 2000 and 2020. Running the unit-root ADF and KPSS tests for stationarity and Johansen's test for cointegration, we decided to rely on the ECM model and ARDL model using the first difference of the time series in order to overcome non-stationarity of our data. Thirdly, we discuss our results regarding the cost-based hybrid NKCP for the Czech Republic and confront our findings with other authors in the field. In the last part of the paper, we summarize the results and formulate policy implications stemming from them.

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