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# Natural Rate of Interest in a Small Open Economy with Application to CEE Countries

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# Presentation plan

1 Introduction – why is natural rate of interest an interesting topic to study?

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2 Model

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☐ Basic Holston-Laubach-Williams specification

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☐ Additions to the model

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3 Sample and data

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4 Results

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☐ Parameter estimates

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☐ Alternative NRI specifications

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☐ Ex-post revisions

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6 Potential growth slowdown

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☐ Growth model

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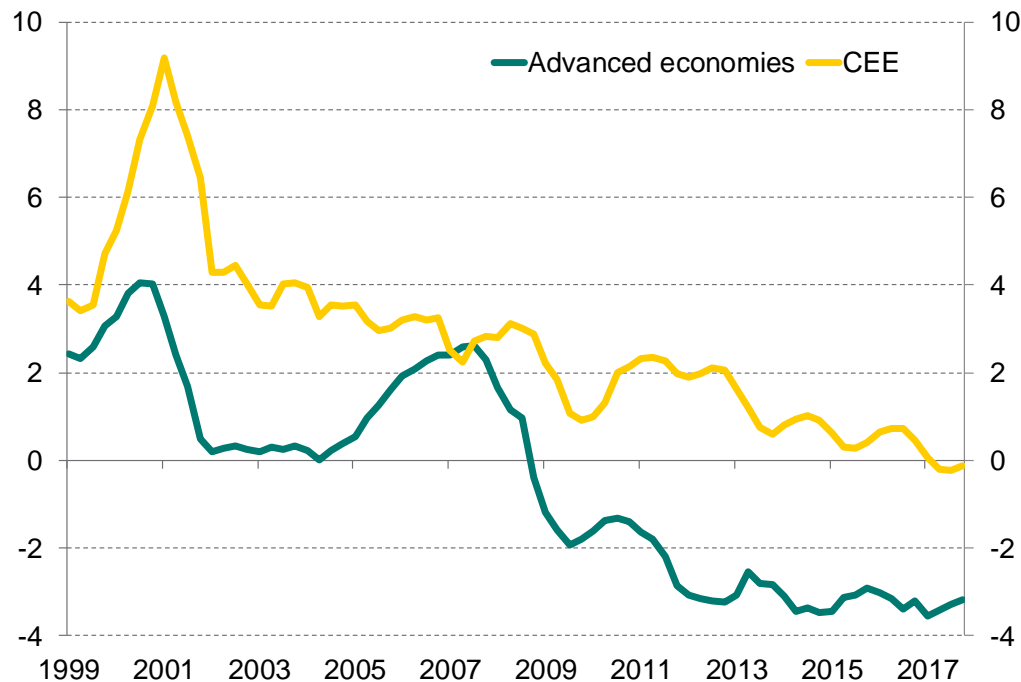
☐ Slowdown decomposition

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7 Conclusions, caveats, policy implications

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## Real interest rates have been on a downward trend since the crisis (or even longer)...

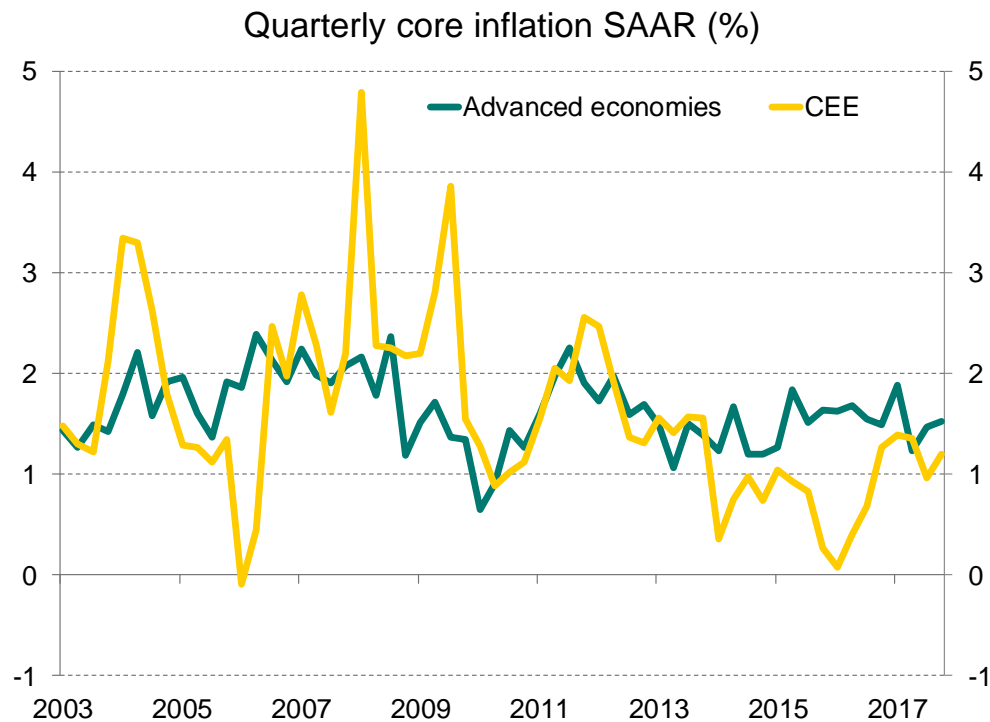


In principle, real interest rate is a difference between central bank benchmark interest rate and annual core inflation. For the US, euro area and the UK, the benchmark rate is replaced with the Wu-Xia shadow rate. For Hungary, 3M interbank offer rate is used.

GDP PPP-weighted indices. Advanced economies: Canada, Euro Area, US, UK. CEE: Czech Republic, Hungary, Poland.

Source: Own calculations based on OECD, Wu-Xia (2017) and Bloomberg data.

## While inflation has remained low



GDP PPP-weighted indices. Advanced economies: Canada, Euro Area, US, UK.

CEE: Czech Republic, Hungary, Poland.

Source: Own calculations based on OECD data.

## Potential explanations

- Inflation has become more dependent on external factors – oil prices, inflation and output gap abroad (i.a. Auer et al., 2017)
- Inflation expectations have fallen (Coibion and Gorodnichenko, 2015)
- The links between interest rates, output and inflation have weakened – the Phillips curve has flattened (i.a. Blanchard, 2016)
- Natural interest rate has fallen significantly (Holston et al., 2017)

I investigate the latter and try to answer why it happened – if it happened

## Natural rate of interest

- It is a real interest rate that would emerge under elastic prices and in the absence of shocks. In such a case inflation is on target and output gap is zero (Woodford, 2003)
- Several methods to estimate it:
  - Small structural model in the spirit of Laubach and Williams (2003): Holston et al. (2017), Juselius et al. (2017), Kiley (2015), Pescatori and Turunen (2015)
  - DSGE model:
    - Short-term concept of NRI: Barsky et al. (2014), Curdia (2015), Del Negro et al. (2017)
    - Steady-state concept: German Council of Economic Experts (2015)
    - Medium-term concept: Del Negro et al. (2017)
  - VAR model: Lubik and Matthes (2015), Del Negro et al. (2017)

## Estimation framework

- I use the framework from the latest study of Laubach and Williams (Holston et al., 2017) as a starting point:
  - Medium-term concept of NRI most relevant from policy perspective
  - Flexibility
- However, it is a simple closed-economy framework not very suitable for small open economies like the CEE countries
- Therefore, I use the open economy new Keynesian model of Gali and Monacelli (2005) as a base to derive the extended, open economy version of the Laubach-Williams framework
- The model is augmented with i.a. the exchange rate, inflation expectations, energy prices, foreign output gap, lending spread and capacity utilisation

## Basic Holston-Laubach-Williams framework

- A system of equations estimated with Kalman filter:

- Phillips curve:

$$\pi_t = \sum_{i=1}^4 b_{\pi,i} \pi_{t-i} + b_y \tilde{y}_t + \epsilon_{\pi,t}$$

- IS curve:

$$\tilde{y}_t = a_{y,1} \tilde{y}_{t-1} + a_{y,2} \tilde{y}_{t-2} + \frac{a_r}{2} \sum_{j=1}^2 (r_{t-j} - r_{t-j}^*) + \epsilon_{\tilde{y},t}$$

- Natural rate of interest:

$$r_t^* = g_t + z_t$$

- Remaining equations:

$$\begin{aligned} y_t &= y_t^* + \tilde{y}_t/100 \\ y_t^* &= y_{t-1}^* + g_{t-1}/400 \\ g_t &= g_{t-1} + \epsilon_{g,t} \\ z_t &= z_{t-1} + \epsilon_{z,t} \end{aligned}$$

## Variables description

$\pi_t$  - core inflation

$y_t$  - ln GDP

$y_t^*$  - ln potential GDP

$\tilde{y}_t$  - output gap

$r_t$  - real interest rate

$r_t^*$  - natural interest rate

$g_t$  - potential GDP growth

$z_t$  - other determinants of natural interest rate

## Amendments to the Phillips curve

- Specification derived from theory:

$$\pi_t = \gamma_f E_t(\pi_{t+1}) + \gamma_b \pi_{t-1} + \kappa(1 + \alpha)\tilde{y}_t + \alpha(\Delta e_t + \pi_t^f) - \alpha E_t(\Delta e_{t+1} + \pi_{t+1}^f) + \frac{(\sigma_\alpha - \sigma)}{(\sigma_\alpha + \varphi)} \kappa(1 + \alpha)\tilde{y}_t^f + \varepsilon_t^s$$

$\pi_t^f$  - foreign core inflation

$e_t$  - ln nominal exchange rate (increase denotes depreciation)

$\tilde{y}_t^f$  - foreign output gap

$\varepsilon_t^s$  - supply shock

- Rewritten Gali and Monacelli (2005) open economy NK Phillips curve augmented with lagged inflation in the spirit of Gali and Gertler (1999) and supply shocks

## Amendments to the Phillips curve

### ■ Empirical specification:

$$\pi_t = \sum_{i=1}^4 b_{\pi,i} \pi_{t-i} + \left( 1 - \sum_{i=1}^4 b_{\pi,i} \right) \pi_t^e + b_{\pi,o} (\pi_{t-4}^o - \pi_{t-4}) + b_e \Delta e_{t-2} + b_y \tilde{y}_t + b_{y,f} \tilde{y}_{t-1}^f + \epsilon_{\pi,t}$$

$\pi_t^e$  - inflation expectations

$\pi_t^o$  - energy price inflation

- Additional lags of inflation kept, lags to other variables chosen to optimise the model fit
- Phillips curve is assumed to be vertical in the long run
- Foreign inflation and expected exchange rate excluded from the specification due to insignificance/wrong sign and reverse causality problems
- Energy price inflation is my measure of supply shocks

## Amendments to the IS curve

- Specification derived from theory:

$$\tilde{y}_t = E_t(\tilde{y}_{t+1}) - \frac{1}{\sigma_\alpha} (i_t - E_t(\pi_{t+1}) - r_t^*) + \frac{\alpha}{\sigma_\alpha(1-\alpha)} E_t(\Delta q_{t+1}) + \alpha \theta E_t(\Delta \tilde{y}_{t+1}^f) + \varepsilon_t^d$$

$i_t$  - nominal interest rate

$q_t$  - ln real exchange rate (increase denotes depreciation)

$\varepsilon_t^d$  - demand (financial market) shock

- Rewritten Gali and Monacelli (2005) open economy NK IS curve augmented with demand (financial market) shocks

## Amendments to the IS curve

- Empirical specification:

$$\tilde{y}_t = a_{y,1}\tilde{y}_{t-1} + \frac{a_r}{2} \sum_{j=1}^2 (r_{t-j} - r_{t-j}^*) + a_e \Delta q_{t-3} + a_f \Delta \tilde{y}_t^f + a_l ls_t + \epsilon_{\tilde{y},t}$$
$$cu_t = \tilde{y}_t + \epsilon_{cu,t}$$

$ls_t$  - lending spread (deviation from mean)

$cu_t$  - capacity utilisation

- Only one lag to domestic output gap, two lags to real rate gap kept, lag to exchange rate chosen to optimise the model fit
- Lending spread (spread between market and central bank rates) is the measure of financial market shocks – Kiley (2015) shows that accounting for it matters for NRI estimation
- The use of survey data significantly improves the accuracy of output gap estimation (Marcellino and Musso, 2011; ECB, 2015; Hulej and Grabek, 2015) and by making output gap partially observable gives the model more power to estimate the NRI ( $z_t$  in particular)

## The exchange rate equation

- Specification derived from theory:

$$\Delta q_t = \Delta(r_t^f - r_t) + (1 - \alpha)\sigma_\alpha E_t(g_t - g_t^f) + (1 - \alpha)\sigma_\alpha E_t(\Delta\tilde{y}_{t+1} - \Delta\tilde{y}_{t+1}^f)$$

$r_t^f$  - real interest rate abroad

$g_t^f$  - potential growth abroad

- Empirical specification:

$$q_t = q_{t-1} + c_g(g_t - g_t^f) + c_y\Delta(\tilde{y}_t - \tilde{y}_t^f) + c_r\Delta(r_t - r_t^f) + \epsilon_{e,t}$$
$$\Delta e_t = \Delta q_t + \pi_t - \pi_t^f$$

- From the model perspective, higher output growth at home should lead to currency depreciation (worsening terms of trade) to assure market clearing
- But, at the same time, real convergence usually leads to price convergence, partially via currency appreciation (Egert et al., 2003; Rubaszek and Rawdanowicz, 2009), while higher output gap in emerging economies tends to cause currency appreciation as a result of a declining exchange rate risk premium (Greszta et al., 2011)
- Hence, the impact of potential growth and output gap differentials on the exchange rate could be ambiguous

## The NRI equation

- Specification derived from theory:

$$r_t^* = \rho + \sigma_\alpha E_t(g_t) + \sigma_\alpha \alpha \theta E_t(g_t^f)$$

- Empirical specification:

$$r_t^* = g_t + z_t$$

- I stick to the Holston et al. (2017) specification
- The parameters of NRI equation are difficult to estimate given the imprecision and fragility of NRI estimates
- The impact of  $g_t^f$  should still be captured by  $z_t$
- Foreign potential growth is explicitly included in the NRI equation as one of the robustness checks

## Sample

- Sample covers the euro area and 3 CEE economies: Poland, Czech Republic and Hungary
- Euro area is used as a proxy for the foreign sector of CEE (~60% of CEE foreign trade is with the euro area) – euro area's output gap, potential growth and real interest rate used as  $\tilde{y}_t^f$ ,  $g_t^f$  and  $r_t^f$
- US treated as a foreign sector for the euro area ( $\tilde{y}_t^f$  and  $g_t^f$  calculated from the HP filter)
- Quarterly data, 1996Q2-2017Q4

## Data

- Inflation and real interest rate calculated similarly as in Holston et al. (2017):
  - Inflation: quarterly inflation excluding food and energy, seasonally adjusted and annualised, from OECD
  - Real interest rate: central bank benchmark rate (from Bloomberg) minus annual core inflation
  - Exceptions: for Hungary I use the 3-month interbank offer rate (similarly as in the euro area, the benchmark interest rate changed there recently) and **for the euro area the Wu-Xia shadow rate** is used so that unconventional policies are taken into account
  - Real interest rate deflated with inflation expectations used as a robustness check

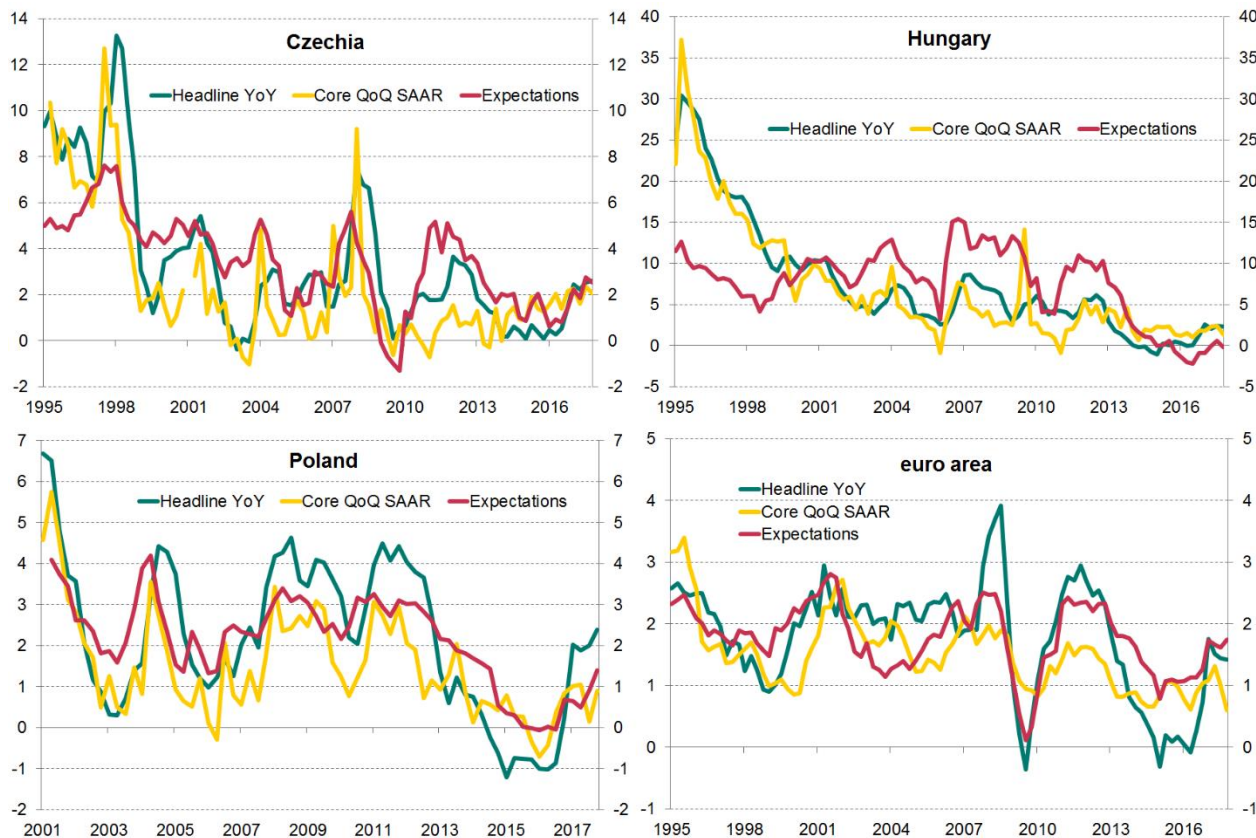
## Inflation expectations

- There are many ways in which inflation expectations can be computed:
  - Perfect foresight: very unlikely to match actual expectations of economic agents, could be subject to reverse causality
  - Adaptive expectations: not an option when past inflation enters the Phillips curve explicitly
  - Surveys of forecasters: most readily available data, but unlikely to capture expectations of actual price setters; forecasts usually revert to the mean which might generate spurious correlation with current/future inflation
  - Surveys of enterprises: perhaps most relevant since firms are price setters; however, the time series are too short
  - Surveys of consumers: seem quite relevant since firms are likely to take consumers' expectations into account when setting prices; however, the survey results are usually not directly transformable into expected inflation
  - Financial market data (inflation-linked bonds): too short time series, shallow markets in CEE

## Inflation expectations

- All things considered, I have opted to use consumer inflation expectations
  - Input data: expected price trends over the next 12 months from the European Commission consumer survey, balance statistics
  - However, this data has to be transformed into expected inflation before it is incorporated into my specification of the Phillips curve
  - Standard methods of balance statistic quantification result in expectations being closely aligned with current inflation, to the extent they are no longer informative
  - Therefore, an alternative method is used - the balance statistic is simply rescaled such that:
    - mean = mean headline inflation
    - variance = 0.6 of headline inflation variance
  - The latter number comes from surveys where consumers are asked a quantitative question (Czech Rep., US and UK; variance of expectations/variance of headline inflation = 0.54-0.67)

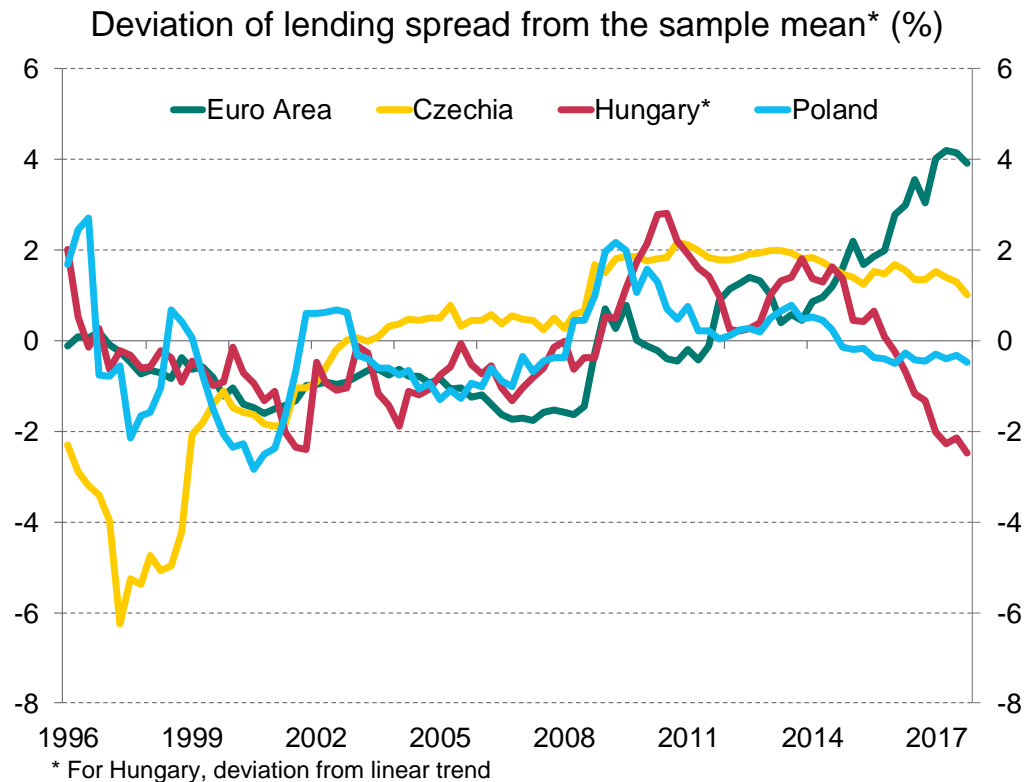
## Inflation expectations



## Lending spread

- In the literature, corporate bond spread is usually used as a measure of financial market shocks (e.g. Kiley, 2015)
- However, CEE economies are bank-dominated and corporate bond markets are shallow
- Therefore, an alternative measure (lending spread) is constructed:
  - Defined as a difference between mean interest rate on new bank loans and central bank benchmark interest rate (the same as the one used to compute real interest rate)
  - Source: central bank interest rate statistics
  - Comparable and comprehensive data available since 2004, for the earlier period either partial data from national sources (Poland, Hungary) or the data from IMF International Statistics Database (euro area, Czechia) is used
  - The deviation of lending spread from the sample mean used in the estimation (for Hungary the deviation from linear trend)

## Lending spread



Source: Own calculations based on central bank and IMF data.

## Other data

### ■ Capacity utilisation:

- Actual capacity utilisation data is mostly unavailable for the service sector
- Percentage of firms reporting insufficient demand as a factor limiting activity has been proposed as a good alternative for the EU countries (ECB, 2015)
- Data source: the European Commission business survey (for Poland GUS)
- Weighted average for services, industry and construction; before 2003 the data for services is not available and hence only industry and construction are included
- Deviation from linear trend with an opposite sign is used in the estimation

### ■ Other data:

- GDP: in constant prices and national currency, from OECD
- Energy price inflation – QoQ, seasonally adjusted and annualised, from OECD
- Real effective exchange rate (increase denotes appreciation) – from BIS

## Estimation

- The model is estimated separately for each country with Kalman filter
- Variances of shocks to state variables are linked:  $\frac{var(\epsilon_{g,t})}{var(\epsilon_{\tilde{y},t})} = \frac{var(\epsilon_{z,t})}{var(\epsilon_{\tilde{y},t})} = \text{variance of HP-filtered potential output growth} / \text{variance of HP-filtered output gap}$
- Prior values and variances of state variables are also taken from HP-filtered data
- Variables which enter with a wrong sign or are highly insignificant are dropped and lags are adjusted to optimise the model fit

## Dropped variables and adjusted lags

Country	Variables dropped	Lags changed
euro area	Phillips curve: $\pi_{t-2}$ to $\pi_{t-4}$ , $\tilde{y}_{t-1}^f$	Phillips curve: $\pi_{t-5}^o$ , $\Delta e_{t-1}$
Czechia	Phillips curve: $\pi_{t-4}^o$ , $\tilde{y}_{t-1}^f$ IS curve: $ls_t$ Exchange rate equation: $\Delta(r_t - r_t^f)$	Phillips curve: $\tilde{y}_{t-1}$
Hungary	Phillips curve: $\tilde{y}_{t-1}^f$	Phillips curve: $\tilde{y}_{t-3}$ IS curve: $\Delta q_{t-1}$ , $ls_{t-2}$ Exchange rate equation: $\Delta(r_{t-2} - r_{t-2}^f)$
Poland	Phillips curve: $\pi_{t-4}^o$ IS curve: $(r_{t-2} - r_{t-2}^*)$ Exchange rate equation: $(g_t - g_t^f)$	IS curve: $\Delta q_{t-2}$ , $\Delta \tilde{y}_{t-1}^f$ Exchange rate equation: $\Delta(r_{t-1} - r_{t-1}^f)$

## Parameter estimates: Phillips curve

Parameter	Euro Area	Czechia	Hungary	Poland
$\sum b_{\pi,i}$	0.939*** (0.000)	0.824*** (0.000)	0.946*** (0.000)	0.709*** (0.000)
$b_{\pi,e}$	0.061 (0.190)	0.176 (0.141)	0.054 (0.308)	0.291*** (0.000)
$b_{\pi,o}$	0.0016 (0.553)	-	0.049 (0.204)	-
$b_e$	-0.0129 (0.187)	-0.118** (0.018)	-0.130*** (0.000)	-0.054 (0.113)
$b_y$	0.027 (0.154)	0.134 (0.102)	0.103 (0.326)	0.048 (0.337)
$b_{y,f}$	-	-	-	0.062 (0.440)

\*\*\* - significant at 1% level, \*\* - at 5%, \* - at 10%

p-values in parentheses.

## Parameter estimates: IS curve

Parameter	Euro Area	Czechia	Hungary	Poland
$a_y$	0.847***	0.940***	0.910***	0.648***
	(0.000)	(0.000)	(0.000)	(0.000)
$a_r$	-0.205**	-0.069*	-0.068	-0.266***
	(0.022)	(0.061)	(0.161)	(0.000)
$a_e$	-0.040	-0.034	-0.063*	-0.029
	(0.181)	(0.268)	(0.080)	(0.375)
$a_f$	0.412***	0.687***	0.681**	0.213
	(0.000)	(0.000)	(0.014)	(0.483)
$a_l$	-0.220*	-	-0.165	-0.425**
	(0.098)		(0.264)	(0.016)

\*\*\* - significant at 1% level, \*\* - at 5%, \* - at 10%

p-values in parentheses.

## Parameter estimates: the exchange rate equation

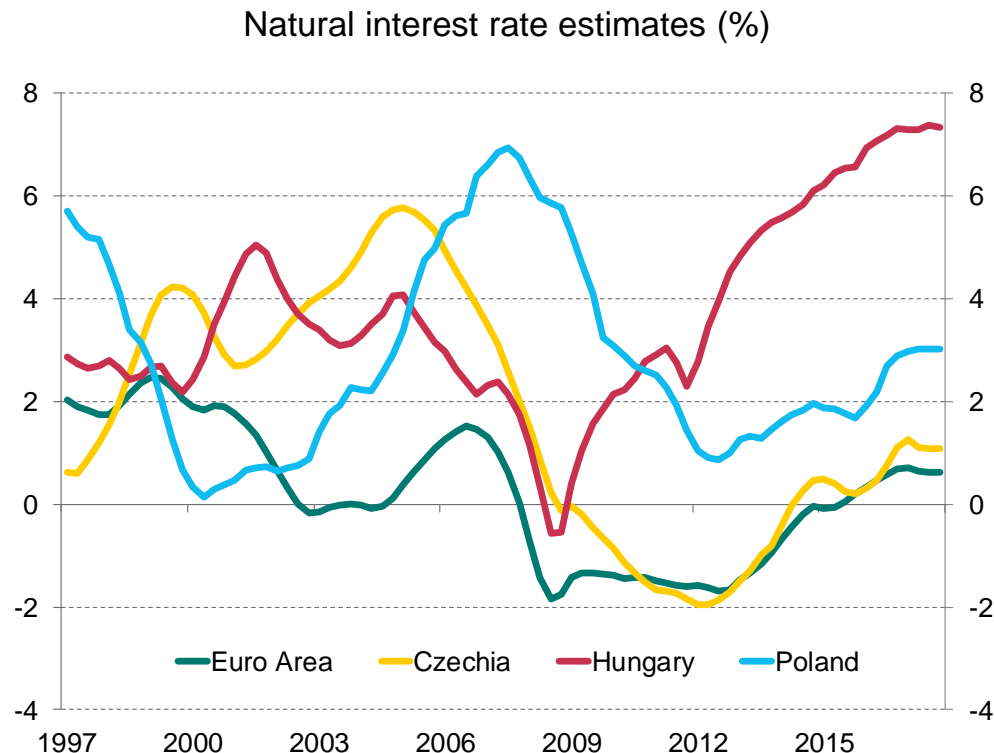
Parameter	Euro Area	Czechia	Hungary	Poland
$c_g$	0.072	0.173	0.406	-
	(0.713)	(0.381)	(0.150)	
$c_y$	-0.048	0.766	-0.246	-1.308***
	(0.927)	(0.199)	(0.658)	(0.007)
$c_r$	0.642	-	0.649	0.903
	(0.237)		(0.177)	(0.130)

\*\*\* - significant at 1% level, \*\* - at 5%, \* - at 10%

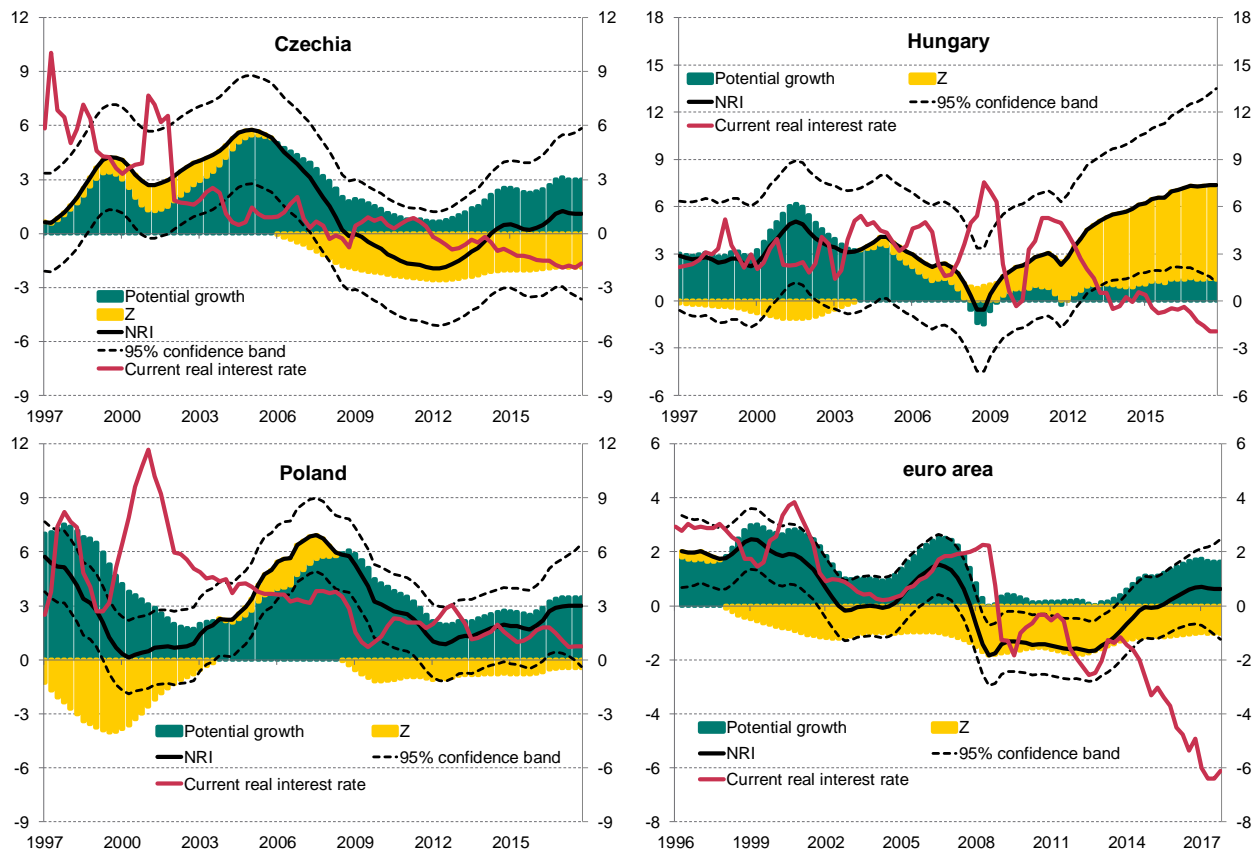
p-values in parentheses.

## Main results

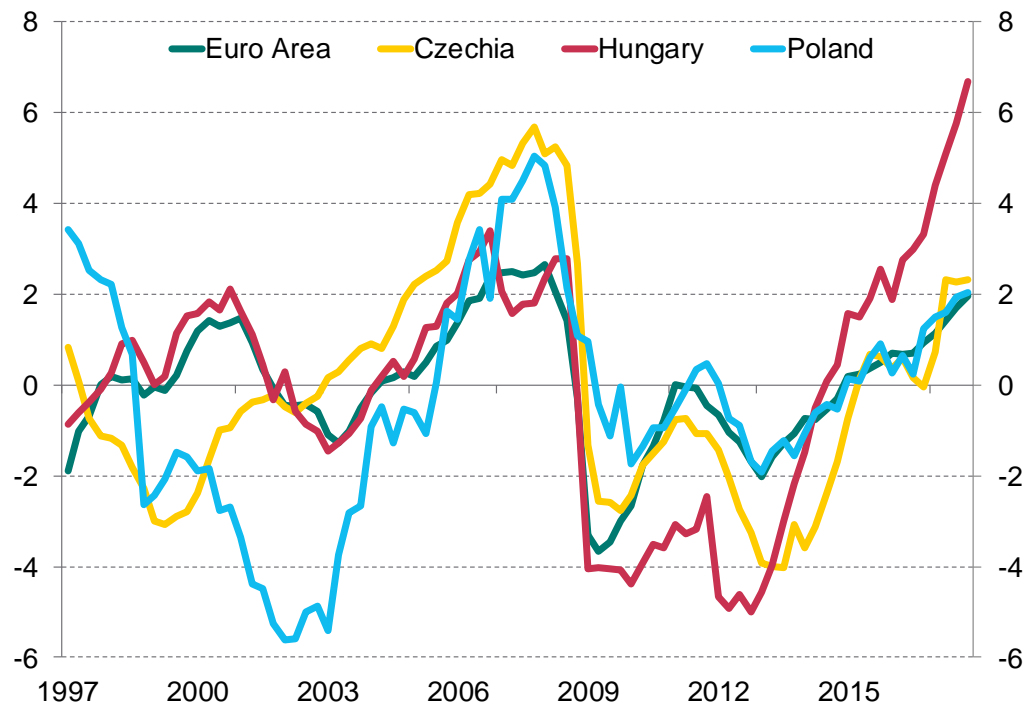
- NRI fell after the crisis but rebounded in recent years
- NRI is procyclical (correlation with output gap 0.32-0.79)
- NRI in Czechia and to some extent Poland comoves with NRI in the euro area
- Hungary – suspicious case



## NRI decompositions (%)



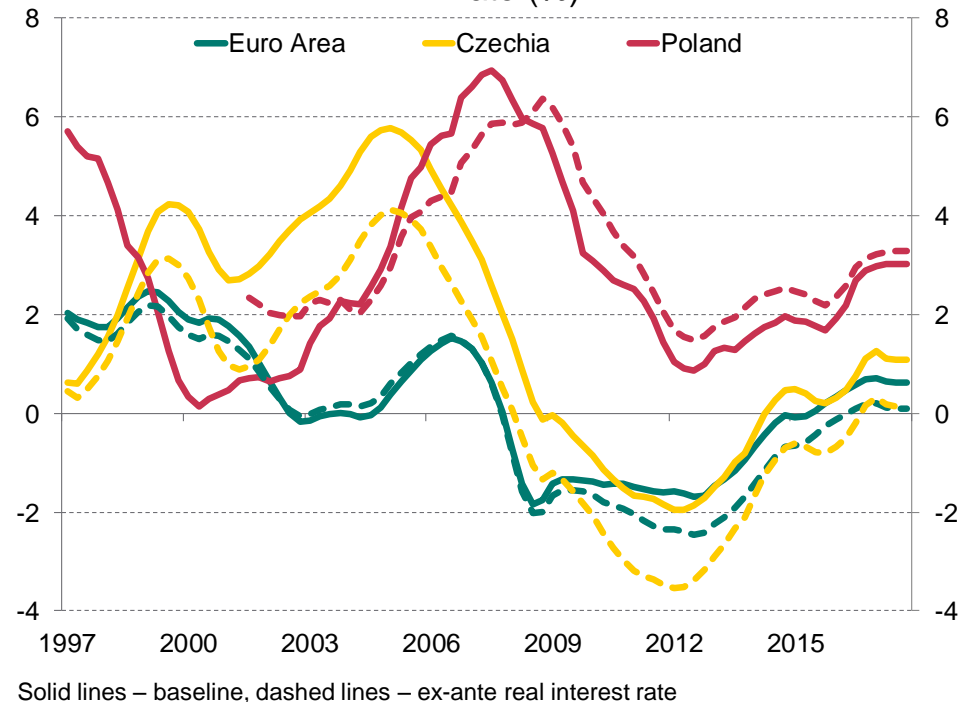
## Output gap estimates (%)



## Robustness checks: ex-ante real interest rate

- Interest rates deflated with consumer inflation expectations instead of annual core inflation
- Some differences in estimates, but for Czechia and the euro area these stem from ex-ante rates being consistently lower than ex-post rates, and for Poland from smaller sample size
- After correcting for these effects, mean absolute deviation < 0.4 pp
- Overall model performance virtually unchanged
- Hungary – results not reported as the IS curve relationship breaks up

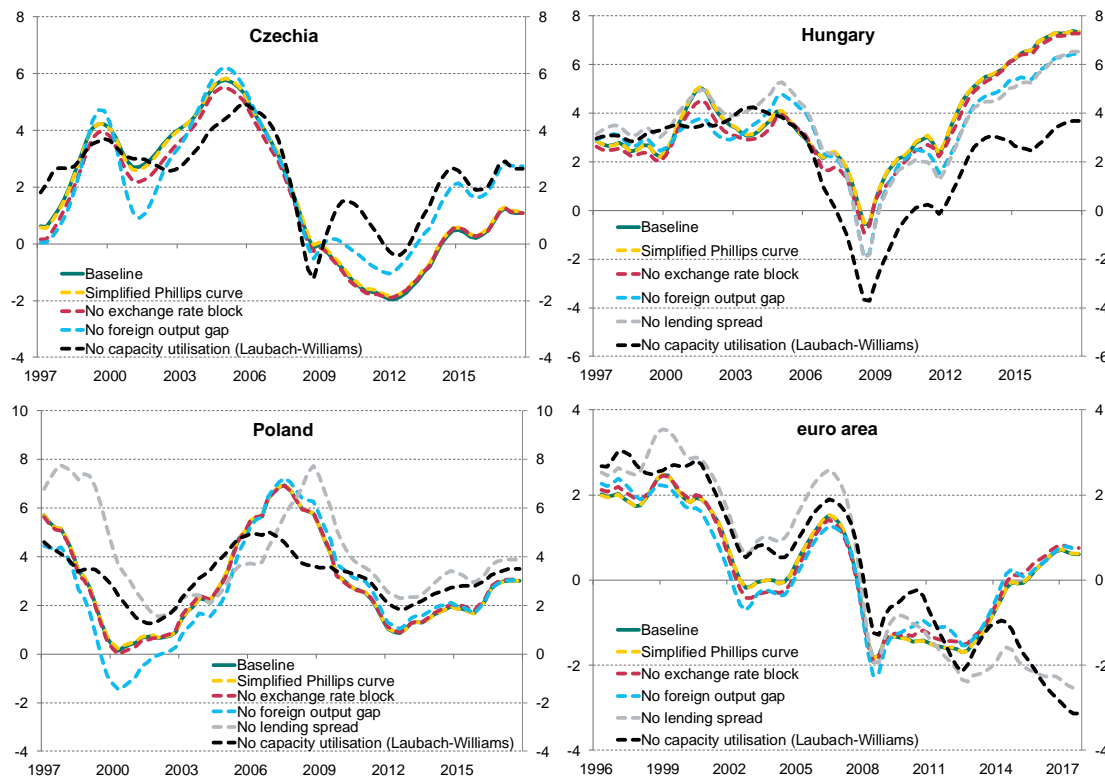
Natural interest rate estimates: baseline vs ex-ante real interest rate (%)



## Robustness checks: excluding variables

- Variables are excluded cumulatively
- Inflation expectations, energy prices, foreign output gap (in the Phillips curve) and the exchange rate can be safely excluded as they have no or little impact on NRI and parameter estimates
- Foreign output gap (in the IS curve) is an important addition that has a significant influence on NRI estimates in CEE (mean absolute deviation of 0.6-0.8 pp)
- Lending spread turns out to be a key addition – without it the slope of the IS curve flattens and as a result, NRI estimates closely track potential growth estimates
- Excluding capacity utilisation has a very large influence on parameter estimates and generates either:
  - flat IS curves and NRI estimates close to potential growth (Poland, Hungary)
  - flat Phillips curves and suspicious output gap estimates (euro area, Czechia)

## Robustness checks: excluding variables



In the simplified specifications, variables are excluded cumulatively e.g. the “no exchange rate block” specification excludes the same variables as the “simplified Phillips curve” specification, plus the exchange rate variables.

Simplified Phillips curve: no energy prices, foreign output gap and inflation expectations in the Phillips curve; No exchange rate block: no exchange rate in Phillips and IS curves and no exchange rate equation; No foreign output gap: no foreign output gap in the IS curve; No lending spread: no lending spread in the IS curve; No capacity utilisation: no capacity utilisation equation.

## Robustness checks: excluding variables

- The latter specification is largely equivalent to the Holston et al. (2017) specification
- The accuracy of my estimates is 2-4 times larger

Mean NRI standard errors (pp)

Specification	Euro Area	Czechia	Hungary	Poland
Baseline	0.58	1.59	2.04	1.05
Simplified Phillips curve	0.58	1.64	2.05	1.04
No exchange rate block	0.56	1.70	2.05	1.06
No foreign output gap	0.49	2.57	1.73	1.09
No lending spread	0.71	-	1.86	4.85
Laubach-Williams	1.91	3.02	3.88	4.15

## Robustness checks: alternative NRI specifications

### ■ Alternative NRI specifications:

$$r_t^* = d_d g_t + d_f g_t^f + z_t$$

$$r_t^* = d_c g_t + (1 - d_c) g_t^f + z_t$$

$$r_t^* = z_t$$

### ■ Specifications with potential growth abroad:

- Parameter estimates not in line with theory and imprecise
- NRI estimates more volatile and at times diverge substantially from baseline

### ■ NRI estimates from agnostic specification look like smoothed baseline estimates (with the exception of Czechia)

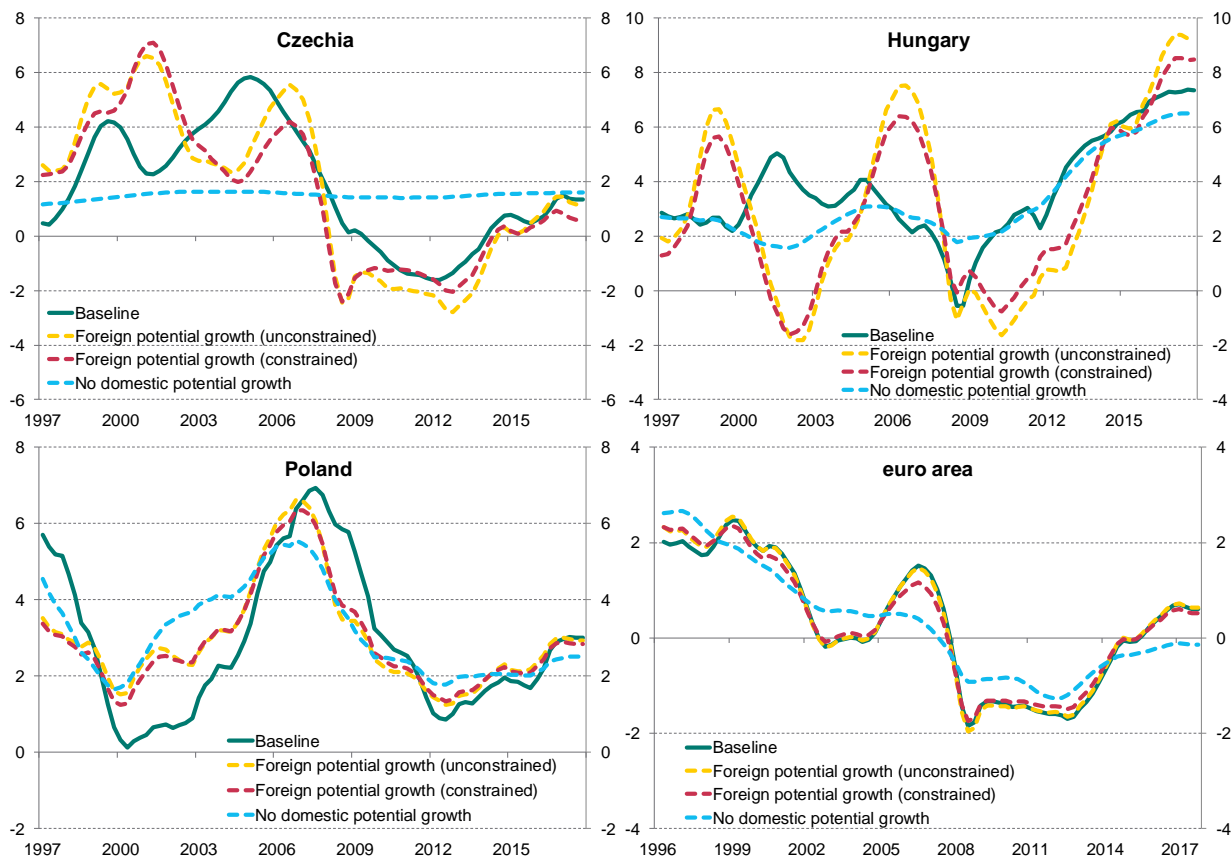
Estimation of alternative specifications of the NRI equation

Parameter	Euro Area	Czechia	Hungary	Poland
$d_d$	1.006	-0.245	-1.395	0.253
	(0.156)	(0.656)	(0.122)	(0.524)
$d_f$	0.212	2.557***	3.225	1.002
	(0.611)	(0.001)	(0.116)	(0.371)
$d_c$	0.752*	-0.837	-1.335	0.283
	(0.065)	(0.177)	(0.124)	(0.456)

\*\*\* - significant at 1% level, \*\* - at 5%, \* - at 10%

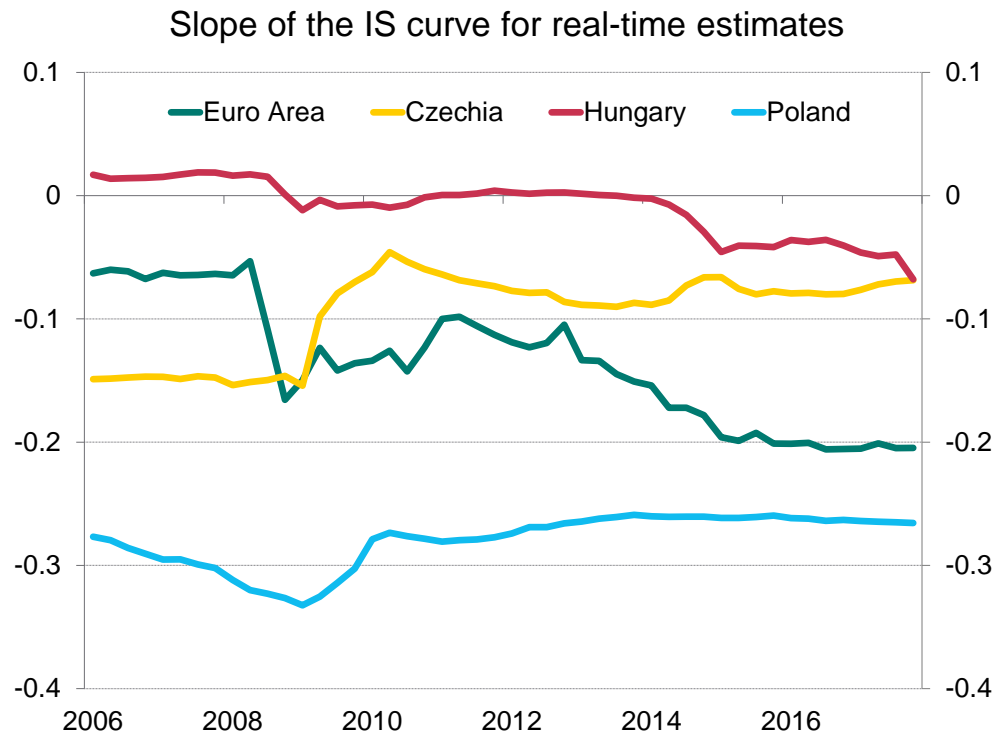
p-values in parentheses.

## Robustness checks: alternative NRI specifications



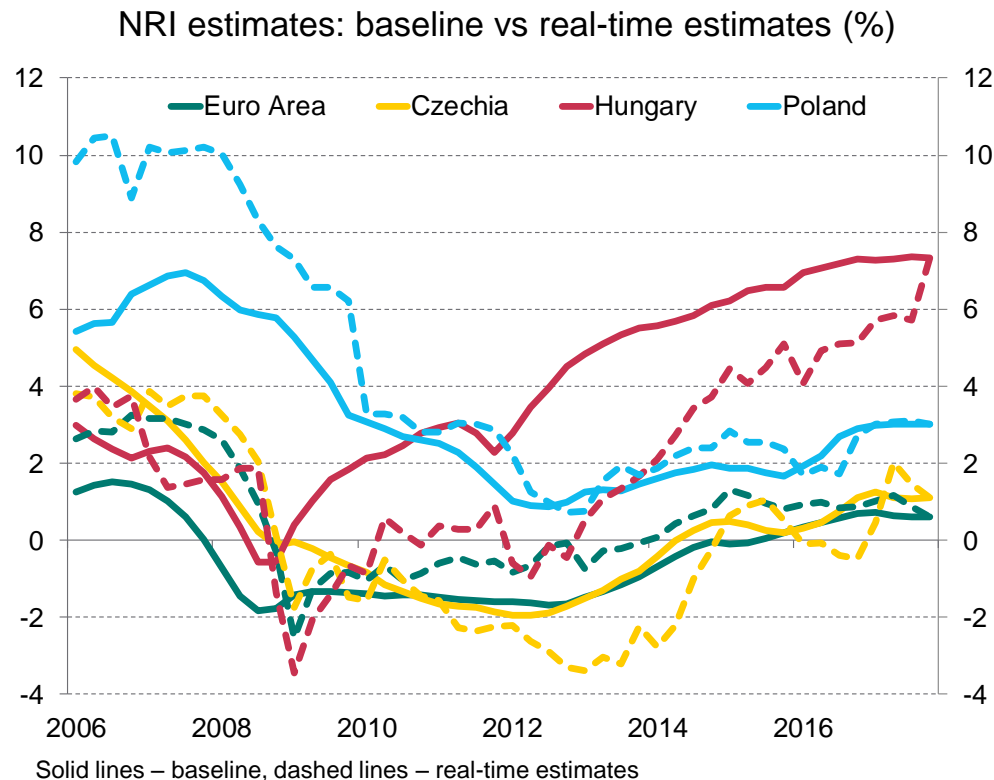
## Robustness checks: ex-post revisions

- The model is run on an extending sample (ending from 2006Q1 onwards) to obtain „real-time” estimates
- Parameter estimates vary substantially over time (especially pre-crisis vs post-crisis)



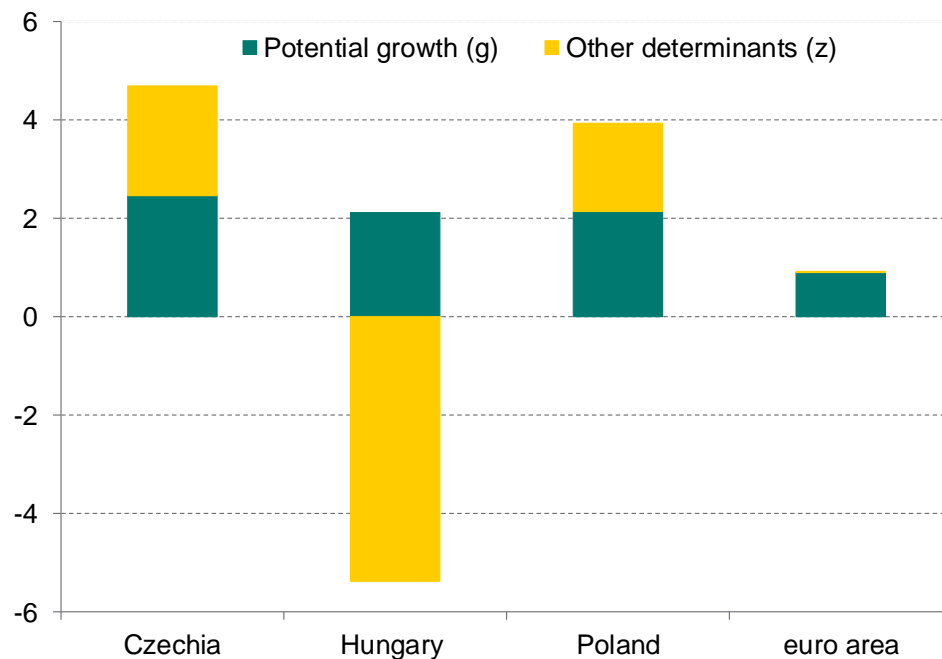
## Robustness checks: ex-post revisions

- Varying parameter estimates, together with differences in input data (detrended survey data), generate significant ex-post revisions in NRI estimates (0.9-2.3 pp on average), especially around GFC and the euro area crisis
- For Hungary, real-time estimates are consistently below baseline, underlining the fragility of its results



## NRI lower than in the pre-crisis peak

The fall in natural interest rate since the crisis (percentage points)\*



\* 2005Q1 for Hungary and Czechia, 2007Q3 for Poland and 2006Q3 for the euro area.

## Potential drivers of falling natural interest rates

	Internal	External
Potential growth	<ul style="list-style-type: none"><li>• Decline in steady state output level</li><li>• Slowdown in population growth</li><li>• Slower rise in labour participation</li><li>• Convergence</li></ul>	<ul style="list-style-type: none"><li>• Slowdown in global TFP growth</li></ul>
Other determinants	<ul style="list-style-type: none"><li>• Population ageing</li><li>• Rising inequality</li><li>• Declining relative price of capital</li><li>• Shifts in preferences (“saving glut”)</li></ul>	<ul style="list-style-type: none"><li>• Population ageing abroad</li><li>• Rising inequality abroad</li><li>• Declining relative price of capital abroad</li><li>• Shifts in preferences abroad</li></ul>

## Decomposing the slowdown in potential growth

- A simple model in the spirit of Mankiw, Romer and Weil (1992) and Islam (1995) is estimated:

$$\left(\frac{Y}{L}\right)_{i,t} = e^{-\lambda} \left(\frac{Y}{L}\right)_{i,t-1} + \alpha i_{i,t} + \beta \ln(n_{i,t} + g + \delta) + \gamma \ln(sch_{i,t}) + \mu_i + \eta_t + \varepsilon_{i,t}$$

$\frac{Y}{L}$  - ln GDP constant PPP per labour force;  $\lambda$  - speed of convergence;  $i$  - ln gross fixed capital formation (% of GDP);  $n$  - labour force growth;  $g + \delta = 0.07$ ;  $sch$  - tertiary school enrolment;  $\mu_i$  - cross-country fixed effect;  $\eta_t$  - time fixed effect.

- Data is annual, covers 47 high income countries between 1991 and 2017, cyclical fluctuations are removed with HP filter
- Estimated with the bias corrected fixed effects estimator developed by Bruno (2005)

## Decomposing the slowdown in potential growth

- Using estimated model parameters, potential growth can be decomposed:

$$g_t = g_t^A + \lambda \left( \left( \frac{Y}{L} \right)_{peak}^{ss} - \left( \frac{Y}{L} \right)_t \right) + \lambda \left( \left( \frac{Y}{L} \right)_t - \left( \frac{Y}{L} \right)_{peak}^{ss} \right) + n_t^{pop} + (n_t - n_t^{pop}) + \varepsilon_{i,t}$$

$$g_t^A = \eta_t - (1 - e^{-\lambda})(t-1) \frac{\eta_t}{t - e^{-\lambda}(t-1)}: \text{global TFP growth}$$

$$n_t^{pop}: \text{working age population growth}$$

$$\lambda \left( \left( \frac{Y}{L} \right)_{peak}^{ss} - \left( \frac{Y}{L} \right)_t \right) = e^{-\lambda} \left( \frac{Y}{L} \right)_{i,t-1} + \alpha i_{i,peak} + \beta \ln(n_{i,peak} + g + \delta) + \gamma \ln(sch_{i,peak}) + \mu_i - \left( \frac{Y}{L} \right)_{i,t-1} + (1 - e^{-\lambda})(t-1) \frac{\eta_t}{t - e^{-\lambda}(t-1)}: \text{convergence}$$

$$\lambda \left( \left( \frac{Y}{L} \right)_t^{ss} - \left( \frac{Y}{L} \right)_{peak}^{ss} \right) = \alpha(i_{i,t} - i_{i,peak}) + \beta(\ln n_{i,t} - \ln n_{i,peak}) + \gamma(\ln sch_{i,t} - \ln sch_{i,peak}): \text{steady state movements}$$

*peak* is the year of pre-crisis peak: 2005 for Czechia and Hungary, 2006 for the euro area and 2007 for Poland

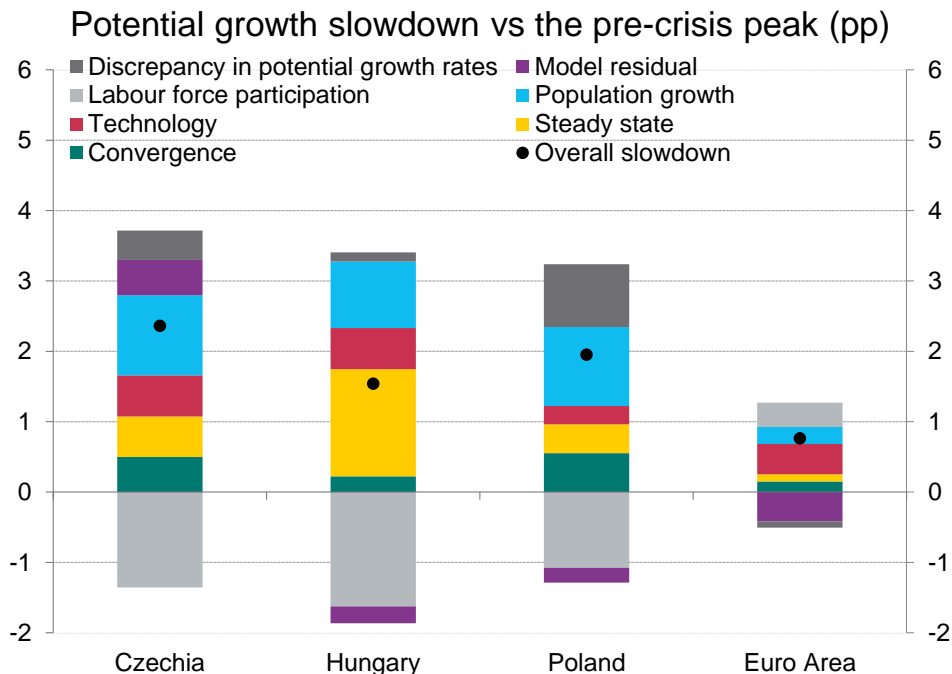
## Growth model estimation results

Variable	Coefficient
$L \cdot \frac{Y}{L}$	0.9838 (0.000)
$i$	0.0514 (0.000)
$\ln(n_{i,t} + g + \delta)$	-0.0437 (0.000)
$\ln(sch_{i,t})$	0.0104 (0.000)
No. of observations	1018
No. of countries	47
R <sup>2</sup>	0.999

p-values in parentheses.

## Domestic factors more important than global factors

- Convergence, a fall in investment/GDP ratio and the slowdown in global TFP growth all played role in CEE growth slowdown
- In Hungary, higher labour force growth and falling school enrolment had an additional negative effect on steady state
- Shrinking working age population was mostly offset by increasing labour participation
- In the euro area, global factors and slower labour force growth most important



Pre-crisis peak in 2005 for Czechia and Hungary, 2006 for the euro area and 2007 for Poland.

The growth slowdown stemming from convergence calculated assuming steady state determinants remain constant at the pre-crisis level.

Dark grey bars show the discrepancy between potential growth rates obtained from the HP filter and the ones estimated from the Kalman filter.

## What's next?

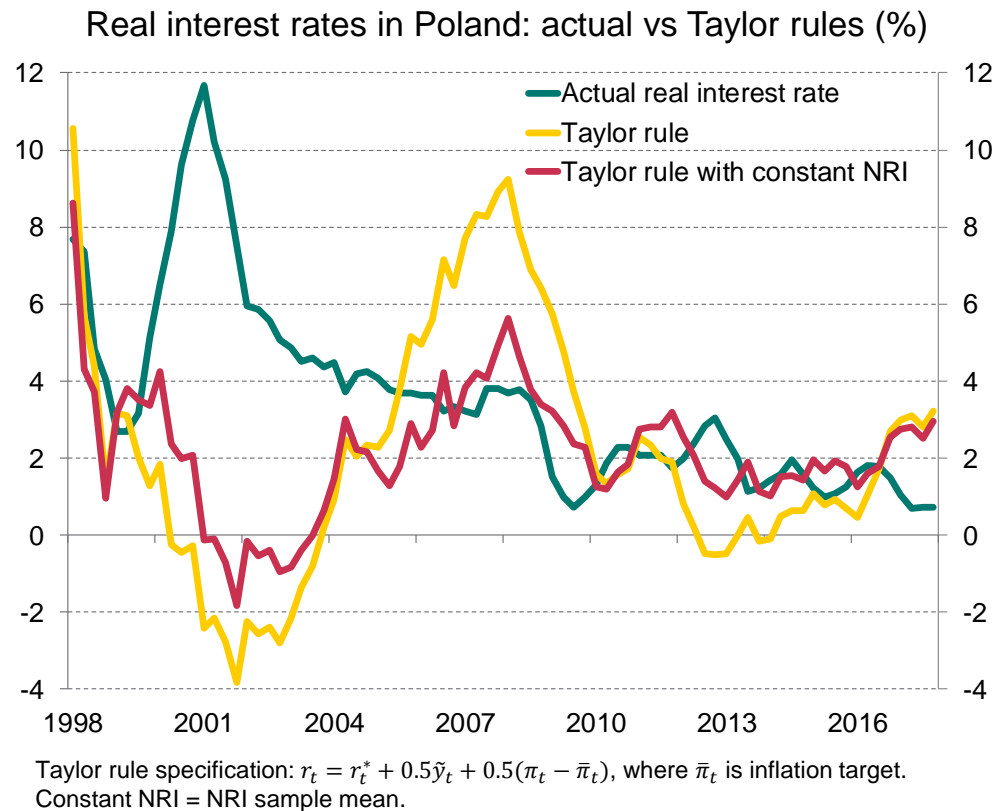
- Other drivers of NRI:
  - For a panel of CEE countries,  $z_t$  regressed on old-age dependency ratio, Gini coefficient, relative price of capital, saving-investment gap and  $z_t$  in the euro area

## Conclusions

- Adding capacity utilisation, lending spread and foreign output gap improves the performance of Holston-Laubach-Williams model and makes it more suitable to study small open economies such as CEE
  - The model has more power to estimate  $z_t$
  - Ex-ante errors decrease substantially
- NRI fell after the crisis and rebounded in recent years, but remains lower than in the pre-crisis peak (in Poland and Czechia by 4-5 pp)
- Both  $g_t$  and  $z_t$  play a significant role in NRI developments
- Domestic factors (convergence and falling investment/GDP ratio) contributed more to potential growth slowdown than global factors

## Policy implications

- NRI procyclical → monetary policy should react to cyclical fluctuations more strongly
- Current stance too loose (in Czechia, Hungary and the euro area way more than in Poland)



## Caveats

- Heavy dependence on survey data → low quality of survey data one of the reasons why NRI estimates for Hungary are doubtful
- Specification of the NRI equation is a soft spot: domestic growth does not seem to be the main driver of NRI in reality (fully agnostic specification better?)
- Parameter estimates are vulnerable to sample choice, which results in large ex-post revisions of NRI estimates
- Growth model is simplistic; in particular, it does not control (well) for cross-country differences in TFP growth

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