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Natural real rates of interest across Euro area countries: Are R-stars getting closer together?

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Natural real rates of interest across Euro area countries: Are R-stars getting closer together?*

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ABSTRACT

Using two different methodologies, we estimate time-varying natural real rates of interest for a majority of euro area (EA) countries, including Lithuania. We find that natural real rates have been declining, particularly since 2008, albeit to different extent across EA countries. Lower rates could (at least partly) be explained by lower productivity and population growth. In line with previous literature, we find evidence of a substantial dispersion of the natural interest rate across EA economies. This became especially evident during the financial crisis of 2008-2009 and the sovereign debt crisis of 2010-2012, while estimates of natural rates tend to converge during "calm" periods. Estimates of natural rates for Lithuania were significantly above the estimates of core EA countries over 2002-2008, but this has changed after the crisis. From 2011 the estimates of natural rates for Lithuania tend to be close to the average for EA countries.

Keywords: Euro area, natural rate of interest, common monetary policy, fragmentation.

JEL codes: C32; E32; E43; E52.

1 Introduction

The natural rate of interest, often denoted by r^*, is an important conceptual benchmark for monetary policy. The concept of a natural interest rate dates back to the end of nineteenth century. Wicksell (1898) suggested that there is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them. He referred to this as the "natural rate of interest". The natural rate of interest, then, is the rate which does not create inflationary or deflationary pressures. As such, it could be called the "neutral" interest rate.

The natural rate of interest has become one of the most important variables in modern macroeconomics. In many macro models, the natural interest rate is the real rate of interest that brings output into line with its potential or natural level in the absence of transitory shocks or nominal frictions (see Woodford 2003, Galí 2015). The natural interest rate is the level of the medium-run real rate that equates investment and savings and, thus, closes the output gap and eventually stabilises inflation. The natural rate of interest is an important conceptual benchmark for monetary policy.

The gap between the natural interest rate and the short-term interest rate set by a central bank (interest rate gap) helps to determine whether the monetary policy stance is loose or tight. If the actual real short term-interest rate is lower than the natural interest rate, the interest rate gap is negative and, thus, the monetary policy could be called expansionary (monetary policy stance is loose). In contrast, if the interest rate gap is positive, the monetary policy is contractionary (monetary policy stance is tight).

As the natural rate of interest is an unobservable variable, one has to estimate it by making assumptions about its behaviour. Such estimations can be found in the literature. We provide a discussion about the challenges of various estimation methods in Section 2. However, in most cases the estimates are highly model-specific and differences among them reflect methodological assumptions, time series properties, and the particular channels that are included or ignored[1].

Many studies have indicated[2] that the downward trend in interest rates observed in most advanced economies is driven by a decreasing natural rate of interest. Holston et al. (2017) estimate that the natural rate of interest in the US decreased from 2.5 % – 3 % in early 80s to around 0.5 % in 2019. Similar trends are observed in Japan, the UK and Canada. This poses a significant problem for monetary policy authorities as it is eroding the so-called policy space. In the absence of any shocks, the nominal interest rate in the economy would converge to the real natural interest rate plus the steady state inflation rate. Due to existing lower bound constraints on how much the nominal interest rate could be lowered by a central bank, the decreasing real natural rates diminish the ability of central banks to deal with economic shocks by adjusting the nominal interest rates.[3]

Comparing the central bank interest rate and the natural rate becomes much more complicated in the euro area (EA) context. Although the EA consists of 19 countries, the central bank sets interest rates by taking into account the macroeconomic situation of the EA as a whole rather than the situation of any particular country. Thus, diverging natural rates of interest across EA economies could pose a major threat when conducting a common monetary policy[4]. Nevertheless, the issue of countries' specific natural interest rates across EA countries has not been extensively analysed[5]. Notable examples are Fries et al. (2018), Fiorentini et al. (2018) and Arena et al. (2020). Fries et al. (2018) estimates time-varying national natural real rates of interest for the four largest euro area economies and shows that diverging national interest rate gaps across these economies already occurred during the boom phase of the first half of the 2000s. Fiorentini et al. (2018) estimates natural interest rates for 17 advanced economies. Arena et al. (2020) use a sample of European countries (including Lithuania and several other EA countries) and find that the decline in natural rate was larger in the advanced European economies compared to emerging Europe.

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[1] For a comparison of various methods used to estimate the natural interest rate, see Brand et al. (2018)

[2] See Constâncio (2016) for discussion

[3] After main central bank interest rates reach 0 % or mildly negative territory, monetary policy faces the effective lower bound (ELB) constraint. Further interest rate cuts become ineffective because it is hard for commercial banks to pass through these rates to depositors. Negative deposit rates on households and corporations may be considered politically inadvisable, and the threat of cashing out savings may increase. Commercial banks could also reduce their reserves held at the central bank by cashing out these reserves themselves.

[4] Our paper is thus somewhat related to the literature on the theory of optimum currency area.

[5] There have been some attempts to analyse differences in monetary policy stance across EA countries. See Gori (2018) and Arena et al. (2020)

There have also been a few attempts to estimate a country-specific natural interest rate for a specific EA country[6]. Our paper contributes to this strand of the literature.

This paper is also related to other strands of academic literature. For example, it is related to the literature on the convergence of EA economies. Comunale et al. (2019) shows that there is still significant heterogeneity in productivity growth across the EA. As natural rates are mainly driven by productivity and the labour market, the convergence in productivity growth should lead to a convergence in natural interest rates. Additionally, the present paper is related to the literature on the heterogeneity of monetary policy transmission across EA countries.

The main contribution of this paper is its analysis of the comovement and convergence of the natural rate of interest across EA countries. We estimate the country-specific natural rate of interest for a majority of EA countries using two different methods. The first method links a few fundamental factors which might determine interest rates in the long run with interest rate by estimating the long-run equation. The second method treats the natural rate of interest as an unobserved variable, and estimates it using a Kalman filter. By using two different methods, we find evidence of a substantial dispersion of natural interest rates across EA economies. This is especially evident during the global financial crisis and the European sovereign debt crisis, as estimates of the natural rate diverged quite substantially during those periods. In contrast, our estimates of natural rates tend to converge during "calm" periods. From 2011 the estimates of natural rates for Lithuania tend to be close to the average of EA countries. However, they were significantly higher than the estimates of core EA countries over the period 2004-2008. While the downward trend in natural interest rates is a well-established fact (see Constâncio 2016, Del Negro et al. 2019), we provide some evidence of a downward trend in natural interest rates on a country level. We show that most of this apparent trend can be attributed to lower productivity and population growth. However, there is substantial heterogeneity across EA countries. It should be noted that the results depend on the method used; thus, there is still a great deal of uncertainty concerning the various estimates[7].

The rest of this paper is organized as follows. In section 2, we present a review of the relevant literature. In section 3, we outline the methodology and discuss the data used in this paper. In section 4, we present our results. A general discussion and implications of our results are provided in Section 5 while Section 6 concludes.

2 Literature overview

Interest rates across the yield curve are trending down; this is a global phenomenon, which is at least partly driven by the decreasing natural rate of interest. As many authors have pointed out, over the past decades, across major advanced economies both short- and long-term interest rates have experienced a significant decline and are currently at historical lows (see fig. 1). Even if looking at a much longer time-span, this substantial decrease is unusual. Del Negro et al. (2019) found that the world risk-free real interest rate, which was roughly stable at a bit below 2% for more than a hundred years, has dropped significantly over the past three decades. Many authors (e.g. Holston et al. 2017, Brand et al. 2019, Rachel & Smith 2017) attribute this decline to the drop in the natural rate of interest[8].

In the remainder of this section, we present the two strands of literature that are closely related to this paper. In subsection 2.1 we discuss the literature that analyses the possible factors which might affect the observed dynamic in the natural rate of interest. In subsection 2.2, we discuss the literature that tries to estimate the natural interest rate across EA countries.

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[6] Slovakia – Kupkovic (2020)

[7] See Brand et al. (2019) for this.

[8] It is worth noting that some authors deny the existence of a natural rate of interest. For example Keynes, in the "General Theory", introduced the concept of an equilibrium of interest rates at different levels of employment, rejecting the idea of real self-equilibrating forces and underlining the importance of monetary factors in determining interest rates even in the long term. While this view is not popular in mainstream economic thinking, it is embraced by many so-called post-Keynesian economists (e.g. Pilkington 2014) (for more extensive discussion see Constâncio 2016).

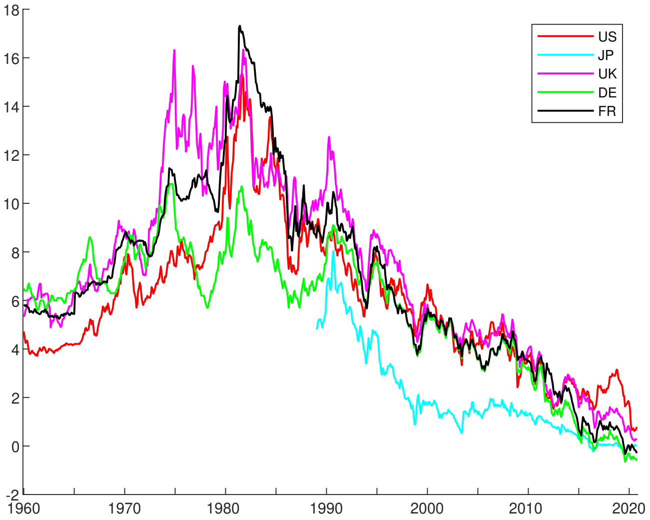

Figure 1: Long-Term Government Bond Yields

Note: The figure denotes the 10-year government bond yield data (monthly average). Source: FRED

2.1 Factors that drive the natural rate of interest.

In this section, we discuss some factors that might affect the natural rate of interest. We focus on three main factors: productivity, demographic factors and risk/term premium. While this does not exhaust the list of factors[9] that have been indicated in the literature, we focus on those we use in our empirical estimation. We briefly mention some other possible factors at the end of this subsection.

Productivity. Many authors (e.g. Lunsford 2017, Gnan & Ritzberger-Grünwald 2005, Del Negro et al. 2019) argue that the natural interest rate has been driven down over the past three decades mainly by productivity. Fiorentini et al. (2018) argue that changes in productivity, by affecting the propensity to invest, seem to play an important role in determining the natural interest rate. This explanation follows the logic of the basic New Keynesian model (such as in Galí 2015), according to which the only source of variation in the natural interest rate is productivity growth. In this respect, Gordon (2010) suggests that the United States and various advanced economies are experiencing a productivity slowdown due to a decline in the innovation rate, which pushes down the natural interest rate.

Demography. Changes in demographic trends may also have an important effect on the natural interest rate, for instance by affecting the aggregate propensity of the economy to save. The literature has emphasized the gradual process of population ageing as having a plausible downward effect on the natural rate. Ageing induces people to accumulate savings during their working lives so as to be able to pay for their retirement. Solow (1956) type models show that population growth is one of the main factors affecting natural interest rate. However, demographic composition might be a better indicator. Fiorentini et al. (2018) note that the United States and many other advanced economies experienced a dramatic baby boom after the Second World War, which temporarily raised the share of young workers in the population. To the extent that the young workers supply labour and have relatively low savings rate, as documented for instance in Higgins (1998), the baby boom might have led to a temporary rise of the natural interest rate. Nevertheless, it is not clear which demographic indicator should be used. Fiorentini et al. (2018) construct a measure of young-age population share, calculated the ratio of the population aged between 20 and 39 over total population, and use this ratio in their model. However, other authors (e.g. Bielecki et al. 2018, Papetti 2019) use growth of working age population (e.g. Bielecki et al. 2018), or ratio of working age to whole population (e.g. Papetti 2019). The exact mechanism through which demographic factors affect the natural rate of interest is not certain. Many argue

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[9] Also, Rachel & Smith (2015) provided a good discussion on various factors, dividing those into demand/supply shifters.

that an ageing society has higher preferences for saving and that this affects the demand for safe assets. Nevertheless, the general growth of the population also might have an affect on the natural rate of interest. If labour and capital are complementary, then slower population growth might reduce the marginal product of capital, as firms have fewer workers to get the most out of their capital stock[10] (see Rachel & Smith 2015, for discussion).

Risk premium. Changes in the risk premium might have also contributed to the decline of natural rates. Fiorentini et al. (2018) argue that a higher risk premium may drive down the natural rate by increasing the propensity of households to save. In this respect, Neri & Gerali (2017) estimate a DSGE model for the United States and the euro area which shows that risk premium shocks, capturing precautionary savings motives due to heightened uncertainty, have driven down the natural interest rate in both currency areas. Related to this logic, Del Negro et al. (2019) emphasize the role of spreads between Treasury and corporate bonds, finding that safety and liquidity premia have reduced the U.S. natural interest rate since the 1990s. Additionally, Van der Ghote (2020) shows that systematic risk reduction could boost risk-free real interest rates in general and the natural rate of return in particular. Fiorentini et al. (2018) use the spread between long-term and short-term interest rates as an imperfect proxy for the risk premium to measure the time-varying risk aversion of the agents. In Arena et al. (2020), the authors argue that in reserve currency areas or countries deemed to be safe havens (for example, Germany in the EA), an increase in uncertainty or risk premia should reduce the risk-free natural interest rate due to the flight to safety or higher propensity to save in that currency. Outside of reserve currency areas, especially in emerging markets, an increase in risk premia might lead to capital outflow, increasing their natural interest rate due to investors' demand for higher return on capital.

Other factors which might have a substantial effect on natural rate of interest. Caballero et al. (2016) and Caballero et al. (2017) argue that a growing *demand for safe assets* from EMEs with less developed financial markets raised global savings during the pre-crisis period, pushing down the equilibrium real rates in safe asset-producing countries (mainly the US). Borio et al. (2019) argued that monetary policy may play a more important role than commonly thought in the long run, including affecting real interest rates. They raise questions about the notion of a natural rate that is independent of policy – in particular a rate that does not even include *financial factors* in its definition. Jordà et al. (2020) reveal how historical data since the 14^{th} century on the 15 largest pandemics suggest that the real natural rate could drop by close to 1.5 percentage points over the next 20 years. They provide evidence that *pandemics* are followed by sustained periods — over multiple decades — with depressed investment opportunities, possibly due to excess capital per unit of surviving labour, and/or heightened desires to save, possibly due to an increase in precautionary saving or a rebuilding of depleted wealth. NGFS (2020) argue that if an economy whose interest rate is already very low or even negative is struck by more frequent, severe *climate* induced natural disasters, this could imply, all else being equal, that the central bank is more likely to hit the zero – or effective – lower bound on policy interest rates. Nevertheless, the effect of climate change on natural interest rate is ambiguous and should be analysed carefully. *Rising income inequality* could also be an important factor in lowering equilibrium real interest rates (see e.g. Rachel & Smith (2015)). A secular increase in income inequality could depress the natural rate of interest if rich households save part of an increase in their permanent income.

2.2 Country level estimates

Country level estimates. Somewhat surprisingly, the issue of countries' specific natural interest rates across EA countries has not been extensively analysed. Nevertheless, some notable examples are Fries et al. (2018), Fiorentini et al. (2018) and Arena et al. (2020), where the authors analyse the country-specific natural interest rate for several EA countries. Additionally, Brand et al. (2018) provide a review of various papers that estimate the country-specific natural interest rates for specific EA countries. However, it is difficult to compare those estimates because the studies used different econometric techniques.

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[10] Most of the empirical papers use the dependency ratio as a variable to account for demographic tendencies. However, in some EA countries (especially Lithuania), population shrinkage driven by emigration was important factor. Thus, in our paper, we use the growth rate of the active population as our demographic variable. Nevertheless, as a robustness check we redid our analysis using dependency ratios and this did not have a significant affect on our main results.

Fries et al. (2018) estimate time-varying national natural real rates of interest for the four largest EA economies (Germany, France, Italy, Spain) over 1999-2016. Fries et al. (2018) results suggest that the natural rate of interest peaked prior to the global financial crisis, i.e. in 2006-2007. They find that the average r^* has been lower after 2008. Furthermore, the national r^* was significantly negative in southern EA countries (Italy and Spain) during the sovereign crisis. As their effective real rates soared, national rate gaps across the euro area diverged. However, a common policy stance has been restored since 2014 as the ECB's unconventional programs gathered momentum.

Fiorentini et al. (2018) estimate natural interest rates for 17 advanced economies. An estimated Panel ECM suggests that the temporary demographic effect of young baby-boomers mostly accounts for the rise and fall of natural rate of interest. They show that those effects are present in the euro area as a whole, and also for some main EA countries[11]. They further demonstrate that demographic factors (which are the main drivers for lower R star) affect all countries, but lower productivity affects only some countries.

Arena et al. (2020) provide estimates of country-specific natural rates and their drivers between 2000 and 2019. They find that the decline in the natural rate is larger in the advanced European economies compared to that in emerging Europe, and this wedge became large during the global financial crisis. Additionally, they provide some evidence of a heterogenous monetary policy stance across major EA countries, and the co-movement of the natural rate of interest in the EA over time.

There have also been a few attempts to estimate a country-specific natural interest rate for a specific EA country using Laubach & Williams (2003) inspired models (e.g. Kupkovic 2020, Arena et al. 2020). Nevertheless we do not know of any EA-wide analysis of country-specific natural rates.

In general, the literature indicates that: (i) natural rates of interest are declining in most advanced economies; (ii) there are many factors which could drive this trend, but, most authors attribute it to lower productivity growth and demographic changes (ageing population, lower population growth etc.); (iii) the trend of declining natural rate of interest is present in the EA as a whole, and also in most EA economies. However, research on country-level natural rates of interest is scarce.

3 Methodology

In this section, we present the two approaches used in the rest of the paper to estimate the country-level natural rate of interest. We also discuss the data needed for those models.

3.1 Neo-classical approach

The first approach we use in this paper is a neo-classical one. We assume that in the long term real interest rates are determined by fundamental factors, while in the short run interest rates can deviate from fundamentals. Thus we link real interest rates with fundamental factors in an atheoretical way[12] (see eq. 2).

$$r_{i,t} = \beta X_{i,t} + \varepsilon_{i,t} \tag{2}$$

$$r^*_{i,t} \equiv r_{i,t} - \varepsilon_{i,t} \equiv \beta X_{i,t} \tag{3}$$

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[11] Austria, Netherlands, Germany, France, Belgium, Italy, France, Portugal, Finland and Spain

[12] While we say that this is an atheoretical way, the idea is highly inspired by neoclassical growth models. In Ramsey (1928)-type growth models, with population growth n and no uncertainty, in general equilibrium the real interest rate in the long run is determined by population growth and productivity. In Solow (1956)-type growth models, demand and supply of capital determines the long-run equilibrium. Thus, if we solve the problem of a social planner who weighs each period's population equally, and the elasticity of intertemporal substitution is equal to 1, we obtain:

$$r^* \equiv g_c + n + \rho \tag{1}$$

where equilibrium real interest rates (r^*) is equal to return of capital, and it moves one-for-one with household's discount rate (ρ) and population growth, (n) and depends on the growth rate in per capita consumption g_c.

where $r_{i,t}$ is the observed real interest rate, and $X_{i,t}$ is a vector of indicators of potential drivers of the natural interest rate. We interpreted the deviations $\varepsilon_{i,t}$ as driven not by fundamental factors.

By estimating equation 2 we assume that in the long run interest rates are driven by fundamental factors, and there cannot be persistent deviations. This is not the case in EA countries. As EA monetary policy is set on area-wide level, interest rates for any specific country could be persistently above or below their fundamentals (especially for small countries). Therefore, in order to calculate EA country-level natural rates, we employ a two-step strategy.

- First, we estimate a long-run equation (2) for various countries which conduct their own independent monetary policy (namely, the US, UK, JP, SE, and CH). By doing so, we get estimates of how various factors affect the natural rate.[13]
- Second, we use those estimated coefficients (β) obtained in the first step and, using EA country-specific data, obtain estimates of the EA country-specific natural rate of interest. (see eq. 3)

The approach we use is somewhat related to Fries et al. (2018). In this paper they first estimate the natural rate using Laubach & Williams (2003) model, and then link those estimates to fundamental factors. In our estimates, we use three fundamental factors which might determine the natural rate of interest: TFP growth, active population growth and risk/term premia. Based on the literature, we expect that higher TFP growth and higher active population growth are associated with a higher natural rate of interest. The theory does not provide clear guidance on how risk/term premia should be associated with the natural rate of interest. Nevertheless, previous empirical estimates (see Fries et al. 2018) find that it contributes negatively. Thus, we expect that term/risk premia should be negatively associated with the natural rate of interest. See section 2.1 for a more detailed discussion.

It is also worth noting how to recover and interpret the natural rates from eq. 2. In eq. 3, we show that the natural rate could be interpreted as $\beta X_{i,t}$, while $\varepsilon_{i,t}$ could be interpreted as short-term deviations. Nevertheless, $X_{i,t}$ could be decomposed also into two components, a structural part $\widehat{X}_{i,t}$ and a cyclical part $\widetilde{X}_{i,t}$ (See eq. 5). In this case, one could argue that the natural rate could be $\beta' \widehat{X}_{i,t}$ – the interest rate part driven only by long-term trends, but not cyclical factors. We think both approaches have merits. We provide the results using eq. 3 in the main section of the paper, and the results with de-trended fundamental factors in the annex B.[14]

$$X_{i,t} = \widehat{X}_{i,t} + \widetilde{X}_{i,t} \tag{4}$$

$$r^*_{i,t} \equiv \underbrace{\beta' \widehat{X}_{i,t}}_{\text{structural part}} + \underbrace{\beta' \widetilde{X}_{i,t}}_{\text{cyclical part}} \tag{5}$$

Data. We use the following data for the regression analysis:

- Long-term interest rate measured as 10-year sovereign bond yield.
- Short-term interest rate measured as deposit, discount or 3-month interbank rate.
- Consumer price inflation rate.

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[13] By linking the fundamental factors with real rates without any lags, we assume that the underlying data generating process is static and that any observed autocorrelation in real rates is driven by autocorrelation in fundamental factors. Somewhat similar approaches have been used by Borio et al. (2019) and Fiorentini et al. (2018).

[14] We estimate the natural rate of interest in three main ways. *First*, we use actual data of the real interest rate and actual data of our fundamental factors in estimating the coefficients β, and then we use actual data to recover the natural rate. This is our baseline (β estimate, provided in Table 1 column 6). The *second* approach is similar to the first in the β estimation part, but we use trends of our fundamental variables in recovering the natural rate i.e. we assume that the natural rate is only the structural part in eq. 5. The *third* way is to use trends of real rates and trends of fundamental factors in our estimation of β and use trends of fundamental factors to recover the natural rate of interest (such β estimates are provided in Table 1 column 9).

- Annual percentage growth of TFP. TFP data retrieved from FRED database for US, Japan, UK, Sweden and Switzerland and from Comunale et al. (2019) estimates for EA economies.
- Annual percentage growth of working age population (age 15-64).

All the data except for TFP are retrieved from Refinitiv Datastream. The time horizon of data is from 1978-1981 (depending on a country, see Table 1 for further detail) to 2017Q4. All data are of quarterly frequency except for TFP in non-EA countries, which are of annual frequency. That data have been interpolated using the same annual TFP growth for each quarter in a given year.

We estimate term premia as the difference between long- and short-term interest rates, and the real natural rate is the difference between the short-term rate and consumer price inflation. TFP and working age population variables are used in their original form.

Estimates. Country-level and panel results are provided in Table 1. There is substantial heterogeneity[15] in estimating each country separately, but a pooled mean group regression provides results that are broadly in line with the existing literature. TFP growth and active population growth yield a positive contribution to the natural rate, while the term premia (spread between long- and short-term interest rates) has a negative impact. If country-specific fixed effects are added, the active population growth stops being statistically significant, but TFP and term premia remain significant and with the expected signs.[16]

In annex A, we provide some additional robustness checks for those results. If measured separately, term spread explains the largest portion of variation in actual interest rates (highest R-squared). The inclusion of the time trend tends to absorb the effect of active population growth[17] as this variable stops being statistically significant. That is an expected outcome, since the active population gradually decreased over time in most of the analysed economies. The growth of TFP and term spread provide more robust results and remain statistically significant using different equations. The TFP coefficient mostly varies in the 0.3-0.5 range while the term spread coefficient is persistent at around -0.6.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dep. var. r	US	JP	UK	SE	CH	Panel	Panel	PMG	Panel-trend
Constant	1.589**	2.198***	2.724***	1.108**	3.086***	1.688***	–	2.141***	1.549***
	(0.56)	(0.12)	(0.43)	(0.42)	(0.28)	(0.13)		(0.36)	(0.12)
TFP growth (YoY)	1.004***	0.047	0.84***	0.02	-0.01	0.43***	0.38***	0.38*	1.28***
	(0.21)	(0.074)	(0.17)	(0.095)	(0.072)	(0.061)	(0.061)	(0.223)	(0.099)
Active Population growth	0.39	1.81***	-1.89**	-1.11**	-1.91***	0.39***	0.69***	-0.54	0.33***
	(0.46)	(0.12)	(0.74)	(0.56)	(0.30)	(0.13)	(0.17)	(0.72)	(0.11)
Term premia	-0.89	-0.85***	-0.88***	0.34***	-0.92***	-0.64***	-0.66***	-0.64***	-0.87***
	(0.13)	(0.064)	(0.12)	(0.12)	(0.06)	(0.048)	(0.051)	(0.24)	(0.058)
R^2	0.32	0.74	0.31	0.098	0.61	0.22	0.22	0.41	0.34
Observations	160	157	156	148	148	769	769	769	636
FE	N/A	N/A	N/A	N/A	N/A	NO	YES	NO	NO

Table 1: Estimates of long run equation

*PMG refers to Pooled Mean Group estimation.
Note: Signs near coefficients reflect confidence intervals. "*" corresponds to 90%, "**" to 95%, "***" to 99%. Standard deviations are shown in the brackets.

Estimates of the real neutral interest rate based on our model are comparable with Holston et al.'s (2017) estimates, produced by the Fed (Figure 2). Our model results tend to be more volatile, especially if every country is measured separately, but longer-term dynamics are similar.

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[15] It is worth noting that imprecision in estimations could mean, that, for smaller countries UK, SE and CH, real interest rates can be affected by global factors. As Galí (2015) shows, the more open the country is, the more its natural rate of interest is driven by global factors.

[16] There is a discussion in the literature on how productivity affects the natural rate. The effect - according to growth models - depends on household preferences for smoothed consumption. Using reasonable estimates, Rachel & Smith (2015) argue that the mapping between productivity growth and real rates may not be one-for-one, but potentially one-for-two, i.e., a 1 pp fall in productivity growth could lead to a 2pp fall in real rates. In our baseline estimates (Table 1 column 6), we obtain that a 1pp lower productivity growth is associated with around 0.4pp lower natural rates. Nevertheless, if we use detrended data in our estimates, the effect increases to 1.28pp. (Table 1 column 9)

[17] We have done all the estimations with other potential demographic variables (e.g. dependency ratio, population growth). These do not significantly alter our results.

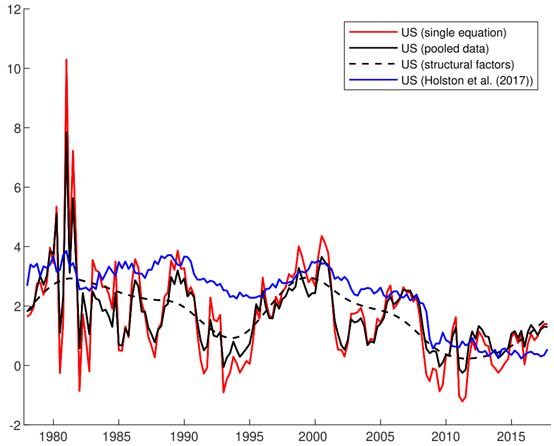

Figure 2: Estimates of the natural rate of interest for US

Note: For the past few years, our estimates for the US have increased. This is mainly due to the declining term premia factor as nominal policy rates have gone up, whereas Holston et al.'s (2017) estimate has been broadly stable or even on some downward path due to a lower estimated growth trend.

Both for the US and the UK, a clear downward trend is evident from the start of 21st century as well as dips in the 1990s and during the GFC in both estimations. The level of the neutral rate also is similar for the majority of the analysed period.

Using the estimates from Table 1, we then calculate the natural rates for EA countries. We provide those results in Section 4.

3.2 Semi-structural model

The semi-structural models proposed by Laubach & Williams (2003) and Holston et al. (2017) are widely used to estimate the natural rate of interest. We use Holston et al.'s (2017) model to directly estimate the natural rate of interest for EA countries[18]. On the positive side, this model lets us consider country specificities, as every country-level model is estimated separately. On the negative side, by design, it assumes that there are no persistent deviations of natural interest rates. This rate is allowed to vary during different periods in response to shocks that emerge on short-term frequencies.

Laubach & Williams's (2003) and Holston et al.'s (2017) empirical approach estimating the natural rate of interest draws on two separate strands of literature. Firstly, they follow Wicksell (1898) in defining the natural rate as the real rate of interest consistent with stable inflation and output being at its natural rate. They build on the New Keynesian framework of a Phillips curve relationship and an intertemporal IS equation to describe the dynamics that govern the output gap and inflation as a function of the real rate gap. Secondly, Holston et al. (2017) relax the steady state assumptions usually embedded in DSGE models to derive log-linear approximations of inflation and output gap dynamics. As the growth rate of technology and the household time preference may expose difficult-to-detect fluctuations (e.g. Stock & Watson 1999), Holston et al. (2017) allow the natural rate to be affected by low-frequency nonstationary processes.

Holston et al. (2017) start from inflation and output gap dynamics described by the open-economy version of the New Keynesian model, but work with reduced-form equations that are somewhat agnostic about the precise lead-lag relationships among endogenous variables. Additionally, they allow for the presence of shocks that affect the output gap and inflation but not the natural rate of interest, which the authors define as a low-frequency concept.

They estimate the following open-economy backward-looking IS curve equation:

$$\widetilde{y}_t = a_{y,1}\widetilde{y}_{t-1} + a_{y,2}\widetilde{y}_{t-2} + \frac{a_r}{2}\sum_{j=1}^{2}(r_{t-j} - r^*_{t-j}) + \epsilon_{\widetilde{y},t} \tag{6}$$

---

[18] While the original Laubach & Williams's (2003) model was calibrated to fit US data, Holston et al. (2017) fits the data of other countries (e.g. Canada, the EA and the UK), which is more suitable for our study.

and a Phillips curve equation of the backward-looking form:

$$\pi_t = b_\pi \pi_{t-1} + (1 - b_\pi)\pi_{t-2,4} + b_y \widetilde{y}_{t-1} + \epsilon_{\pi,t} \tag{7}$$

where $\widetilde{y}_t = 100 \cdot (y_t - y_t^*)$,$y_t$ and y_t^* are the logarithms of real GDP and the unobserved natural rate of output, respectively, r_t is the real short-term interest rate, π_t denotes consumer price inflation, and $\pi_{t-2,4}$ is the average of its second to fourth lags. The presence of the stochastic terms $\epsilon_{\widetilde{y},t}$ and $\epsilon_{\pi,t}$ captures transitory shocks to the output gap and inflation, whereas movements in r_t^* reflect persistent shifts in the relationship between the real short-term interest rate and the output gap.

Holston et al. (2017) further assume the law of motion of the natural interest rate:

$$r_t^* = g_t + z_t \tag{8}$$

where g_t is the trend growth rate of the natural rate of output and z_t captures other determinants of r_t^*.

They apply the state space model to jointly estimate the natural rate of interest, potential output, and its trend growth rate, and examine the empirical relationship between these estimated unobserved series.

In our estimation procedure, we closely follow Holston et al.'s (2017) model. We employ the same three-step estimation method as described in their paper:

1. apply Kalman filter to estimate the natural rate of output without the real rate gap term;
2. include the real interest rate gap in the output gap equation and estimate the five model equations;
3. estimate the remaining model parameters by maximum likelihood procedure with the help of estimated values from steps 1) and 2).

However, we apply *reasonable* caps on the IS and PC slope coefficient that differ from the ones used in Holston et al. (2017). As it is often discussed in the literature, the flatter PC becomes and the steeper the IS curve becomes, the harder it is to reasonably estimate the natural rate of interest. This is even a bigger problem if one uses a short time series, which is the case in our estimation. As the original Holston et al. (2017) model used data (and accompanying parameters) for the period since the early 1970s (which was crucial for Holston et al. (2017) to obtain reasonable results), we updated the floors of IS/PC slopes to make them more similar, with more recent estimates for shorter horizons, such as Fries et al. (2018) and Eser et al. (2020).[19] We applied the same floors for all EA countries under our analysis. Still, as cautioned by Holston et al. (2017), the obtained results are median estimates with a high level of uncertainty; thus, the interpretation of the coefficients and statistical significance of statistical models should be approached with caution. Additionally, the results depend on the variables used and the length of time-series data.

4 Results

In this part, we provide outcomes from neo-classical and semi-structural models.

4.1 Neo-classical approach

In this section, we provide estimates of our first-stage regression. We link the real interest rate to TFP, demographic factors and term premia.

Real natural interest rates were persistently higher in Lithuania before the crisis than in most other EA economies, but fell much more significantly afterwards. This effect stems largely from the TFP and term spread (Figure 3b) as Lithuania, with its small and open economy, was hit harder by the crisis than most other EU countries. This led to a larger decline in productivity and a spike in long-term yields. After the initial shock, the neutral rate in Lithuania converged to that found in major euro area economies and has remained at a similar level until now. Compared to

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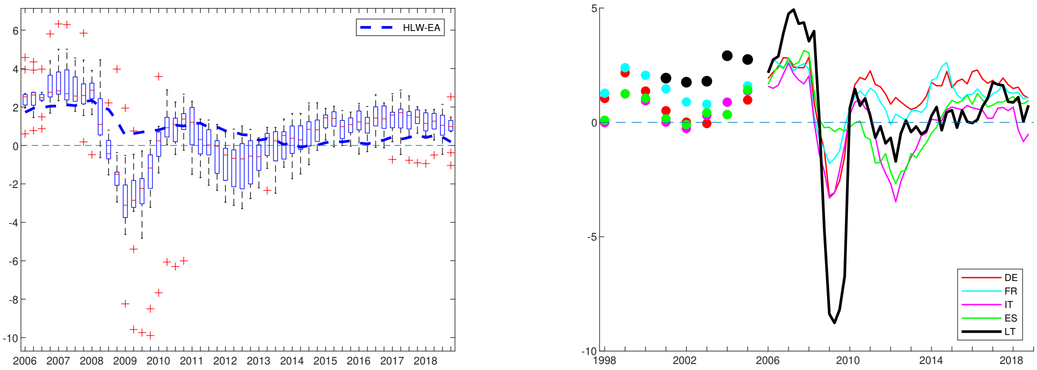
[19] It is worth noting that Holston et al. (2017) also put caps on those coefficients, albeit not such restrictive ones.

the estimates presented by Holston et al. (2017) for the euro area, our results are broadly in line for the EA median. A notable exception was the 2008-2009 crisis, when our estimates fell much more significantly but quickly rebounded afterwards.

Among major EA economies, there is some heterogeneity in neutral rate estimates, but the overall dynamics tend to be similar. For the most of the analysed period, the neutral rate in Italy has been on the lower side, while in Germany it was mostly higher. In all major economies, the most recent natural rate estimates are lower than before the GFC.



(a) Distribution of r^* across EA countries

(b) Distribution of r^* across big EA countries and Lithuania

Figure 3: Estimates of natural rates of interest

Note: Blue dashed line (Figure 3a) denotes the estimates of natural rate of interest provided by Holston et al. (2017). Dots (Figure 3b) denote extension of estimates using annual data.

Decomposition of the factors contributing to neutral rate developments in different countries also provides some useful insights (Figure 4). As expected, changes in term spread played a more important role in suppressing neutral rates in Italy and Spain and is also the key factor behind the neutral rate divergence with France and Germany. Heterogeneity in TFP and demographics contributes to a lesser extent. Lithuania differs from other larger EA countries due to its higher volatility, especially the negative contribution from TFP and term spread during the GFC. In addition, the contribution from active population growth is persistently negative in Lithuania while this not the case in the major EA economies.

4.2 Semi-structural estimates

The results from the applied Holston et al.'s (2017) model have revealed that the real natural rates in most EA countries have been on a declining trend, but wide differences still exist across member states (Figure 5). The results with data of 13 EA countries since 1997 have shown that almost all member states experienced substantial decreases in their respective real natural rates[20]. However, the size of the slump was rather different among countries reflecting heterogeneity in level of initial rates and changing strength of domestic economies. The decline was much less pronounced for countries that had the lowest rates at the start of the sample period (e.g. Germany, Italy and France), while the natural rate slumped the most in countries with the highest initial rates (e.g. Latvia and Lithuania). The EA average, as provided by Holston et al. (2017), shows a similar (though less volatile) trend.

The overall trend of declining natural rates in EA countries was not linear. On average, natural rates increased rather substantially until the onset of the GFC in 2007-2008 together with cyclical developments of increasing output gaps. Soon after the GFC erupted, the natural rates dropped and reached their lowest levels in most EA countries (in many cases – even negative ones) in the

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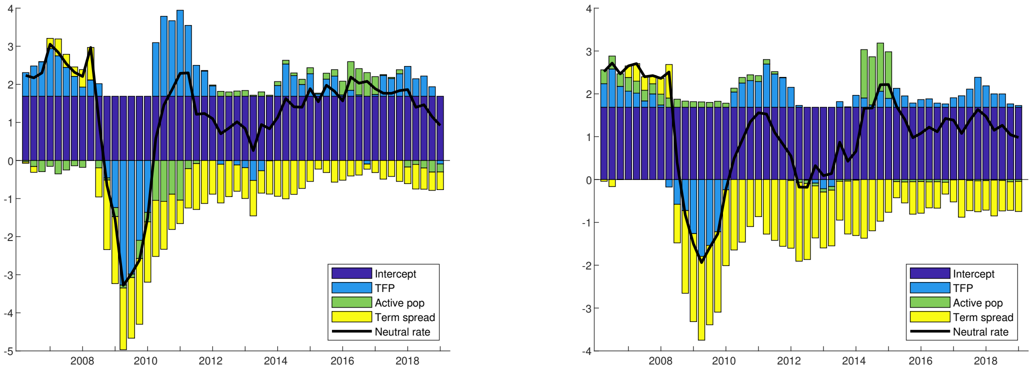
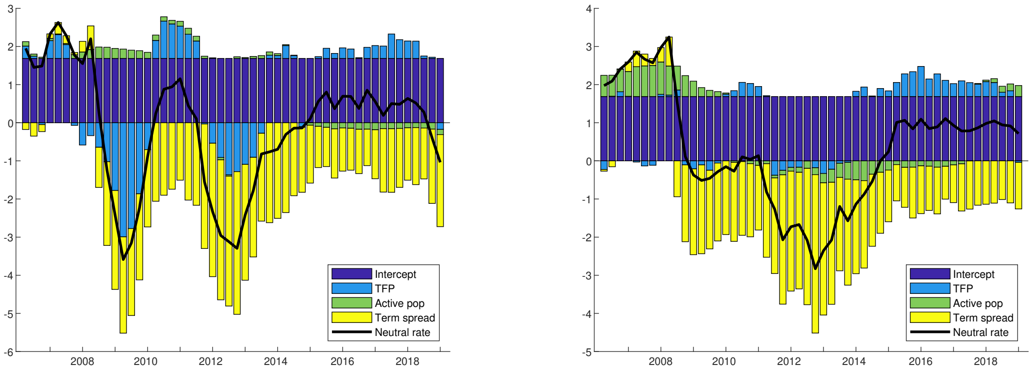
[20] Countries for which we could obtain results are: Austria, Belgium, Cyprus, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Portugal and Spain. We could not obtain results for 6 EA countries due to the data limitation (i.e. uniform data since 1997) that was necessary for the Holston et al.'s (2017) model estimation. The results for Ireland and Latvia should be assessed with caution due to rather volatile time-series for these countries.

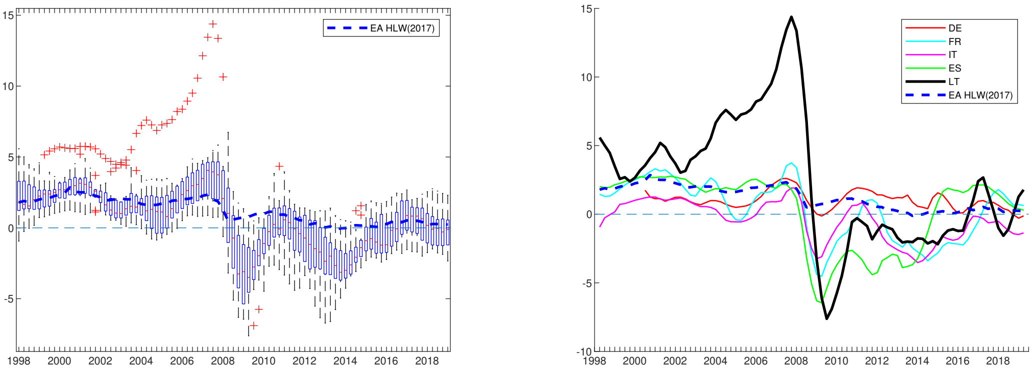


(a) DE **(b)** FR



(c) IT **(d)** ES

Figure 4: Drivers behind the changes in r^* across some EA countries
Note: Decomposition is calculated using the panel estimates provided in Table 1



(a) Distribution of r^* across EA countries **(b)** Distribution of r^* across larger EA countries and Lithuania

Figure 5: Estimates of natural rates of interest using semi-structural model
Note: Blue dashed line denotes the estimates of natural rate of interest provided by Holston et al. (2017)

second half of 2009. Afterwards, real natural rates started increasing in line with closing output gaps, but then again adjusted downwards during the European sovereign debt crisis in 2010-2012. Since then, real natural rates have been fluctuating in a relatively narrow range in most EA countries. Overall, it is obvious that the general decline of real rates over more than a 20-year period has been most pronounced during major economic setbacks.

The real natural rate was much higher and more volatile in Lithuania until the end of the

GFC, but then the size and dynamics of the rate converged to those found in major EA economies (Figure 5b)[21]. The real natural rate in Lithuania increased at a much faster pace than in other EA countries until around 2008. This was led by the convergence processes, when Lithuania's potential growth was much faster than in advanced EA economies. During the GFC, the slump of Lithuania's economy and, accordingly, the decrease of the real natural real rate, was much stronger than in other EA countries. As Lithuania's small and open economy grew unsustainably until 2008, it was extremely exposed to external shocks and disrupted capital flows during the GFC. However, the following economic adjustment and structural reforms (including the convergence that was necessary for the euro adoption) soon contributed to an increase of the real natural rate which, since around 2011, began fluctuating rather similarly as in other EA countries, including the largest ones. Still, there was an evident short-term spike in the real natural rate in Lithuania in 2017 as economic growth as well as inflation (and inflation expectations) increased rather substantially. The result of a highly volatile Lithuanian natural rate as well as normalisation after the GFC was also obtained by IMF (2019), which attributed these changes to the dynamics of TFP growth and extremely severe demographic trends.

5 Discussion and policy implications

Although our results are broadly in line with many other estimates, our two different approaches provide somewhat different results. Such development is present in many other studies, as results highly depend on methodological assumptions and the size of countries under analysis. Our results are similar to the ones provided by Fries et al. (2018) and Fiorentini et al. (2018). Arena et al. (2020) provide estimates of natural rates of interest for the 5 biggest countries in the EA and Lithuania. Their estimates are somewhat similar to ours, albeit in some specifications their estimates for Lithuania are persistently above the estimates of other countries. This contrasts with our results, as we obtain that natural rates in Lithuania were substantially higher pre-2008, but are broadly in line with other countries after the crisis.

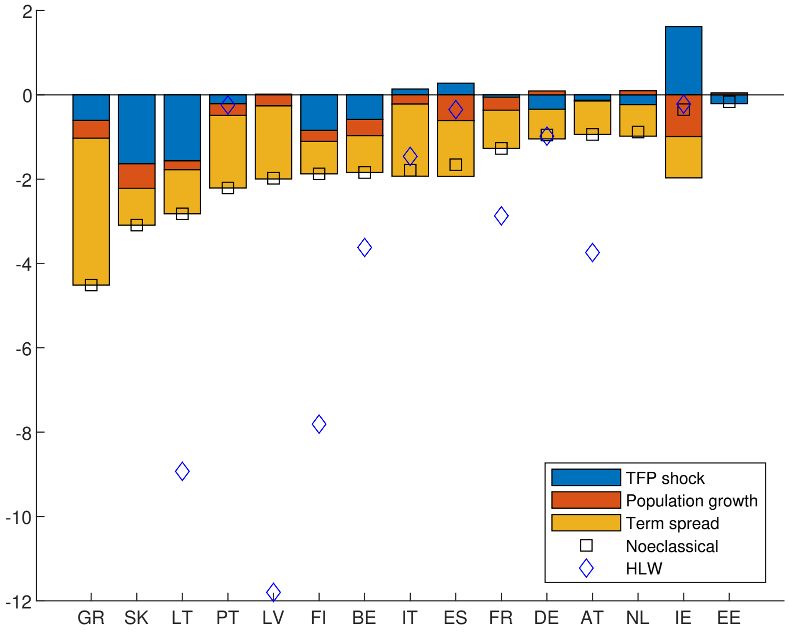


Figure 6: Drivers behind changes in r^* acros EA countries: 2006-2007 compared to 2017-2018

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[21] As Lithuania experienced substantial economic and structural transformations in the past 30 years, the model results were rather sensitive regarding the length of time-series data as well as model inputs. However, the overall dynamics of the real natural rate were quite similar irrespective of the model specification. Thus, the results should be interpreted less from a neutral rate standpoint than from a perspective of changes over time.

There is limited convergence across EA countries. Convergence between natural rates among EA countries has been estimated as a standard deviation across EA countries' neutral rate. The results show that natural rates diverged during the GFC and reached their highest fragmentation level during the European sovereign debt crisis, but fell significantly afterwards (Figure 7). Currently, the degree of divergence remains at a level similar to the period 2006-2007. If decomposed by the factors contributing to these developments, we see that the major impact comes from the term spread. Deviation increased, especially in peripheral economies, during the European sovereign debt crisis. The contribution from TFP become significantly more important during the GFC, but tended to be lower in more recent periods, while active population did not contribute significantly to the divergence among natural rates in the EA for the whole time horizon. Additionally, it is crucial to account for composition of the EA because, for example, Lithuania, Latvia and few other countries experienced extremely large volatility in natural rates over the GFC, but at the time these countries were not part of monetary union.

Natural rates of interest are trending down even on the EA member states' level. We can see from Figure 6 that in all estimated EA countries, natural rates are lower compared to the period 2006-2007. Nevertheless, this downward trend is driven by different factors. Term spread plays a major role for most countries, but the contribution of TFP and active population growth is more heterogeneous. TFP has been the main negative contributor in Lithuania, Slovakia and Finland, but even had some positive impact in Ireland, Italy and Spain. Growth of active population also had a significant negative contribution in some countries (particularly in Ireland, Slovakia and Spain), but virtually no impact in others.

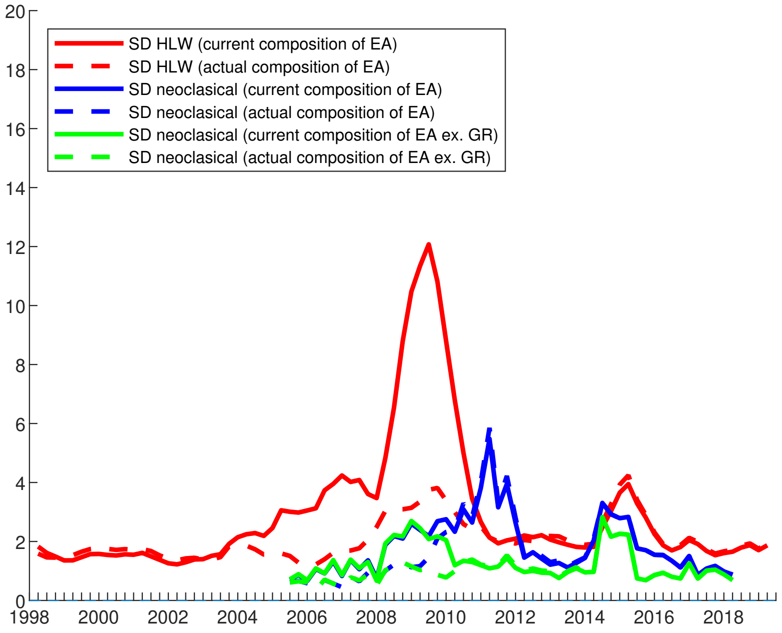

Figure 7: Standard deviations of r^* across EA countries

Our results on natural real rate developments in different EA economies also provide some policy implications. Clear divergence in equilibrium rates during crisis periods implies that common monetary policy may not always be sufficient to fully address heterogeneous shocks in some countries. In such periods, country-specific policies like fiscal and macroprudential measures are of crucial importance. In addition, we estimate that in some southern Europe countries, natural rates tend to be persistently below those found in Germany.

6 Conclusion

In this paper, we estimate time-varying natural real rates of interest for a majority of EA countries, including Lithuania. To do so, we employ two methods, and we compare the results between them as well as with results from similar studies. The first approach, a "neoclassical approach" – directly links real interest rates with fundamental factors (such as productivity and demographic trends). The second approach, a "semi-structural approach" – was proposed by Laubach & Williams (2003) and then expanded by Holston et al. (2017). Although these approaches are different, the revealed dynamics are rather similar.

It is worth bearing in mind that the estimation of the natural rate of interest is highly uncertain and depends on a variety of factors and time-span of the analysis. Thus, rather than looking at the size of the point estimate for a broad idea of the dynamics in natural rates of interest, one might instead look at general trends. The estimates provided in this paper also suffer from this uncertainty. Moreover, there may be many other channels that affect the natural rate of interest which we might have missed. Thus, our estimates (as other authors') should be approached with caution. Still, to the best of our knowledge, this paper provides estimates of the natural rate of interest for the largest subset of EA member states.

We find that average natural real rates have been declining, particularly since 2008, albeit to different extents across EA member states. Lower rates could (at least partly) be explained by lower productivity and population growth. In line with previous literature, we find evidence of a substantial dispersion of the natural interest rates across EA economies. This was especially evident during the global financial crisis of 2007-2009 and the European sovereign debt crisis of 2010-2012. However, the estimates of natural rates tend to converge during "calm" periods. Overall, the decline was much less pronounced for countries that had the lowest rates at the start of sample period, while the natural rate decreased the most in countries with highest initial rates.

Estimates of natural rates for Lithuania were significantly above the estimates of core EA countries over 2002-2008, but this changed after the crisis. From 2011 on, the estimates of natural rates for Lithuania tend to be close to the average of EA countries. The main factors driving substantial decrease in the estimates of natural rates for Lithuania since 2006-2007 were term spreads and, in particular, lower TFP growth.

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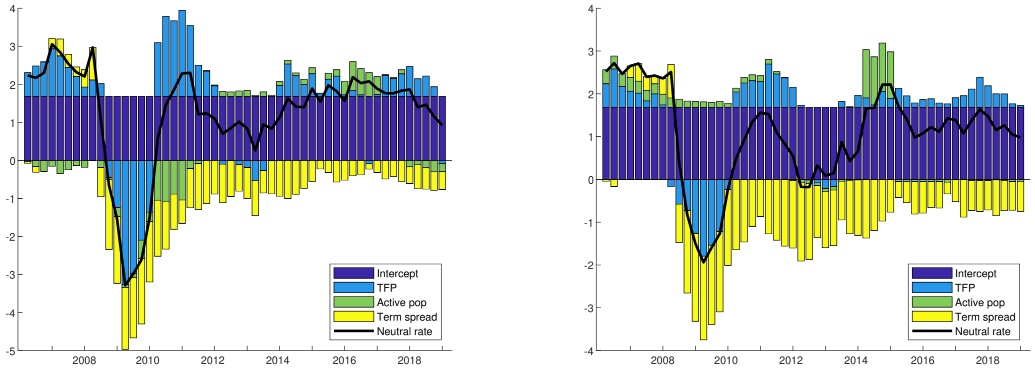
A Robustness checks of long run equations

Dep. var. r	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Constant	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TFP growth (YoY)	0.335***	0.389***	0.210**	0.380***			1.148***	0.340***	0.386***	0.200***	0.369***				
Population growth			1.061***	0.694***		0.903***				0.053	-0.294		-0.291	-0.013	
Term premia		-0.706***		-0.659***	-0.606***	-0.551***			-0.694***		-0.624***	-0.618***	-0.548***		
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.03	0.22	0.05	0.22	0.15	0.16	0.05	0.08	0.35	0.26	0.42	0.33	0.42	0.29	0.08
Observations	824	808	773	769	849	809	813	824	808	773	769	849	809	813	865

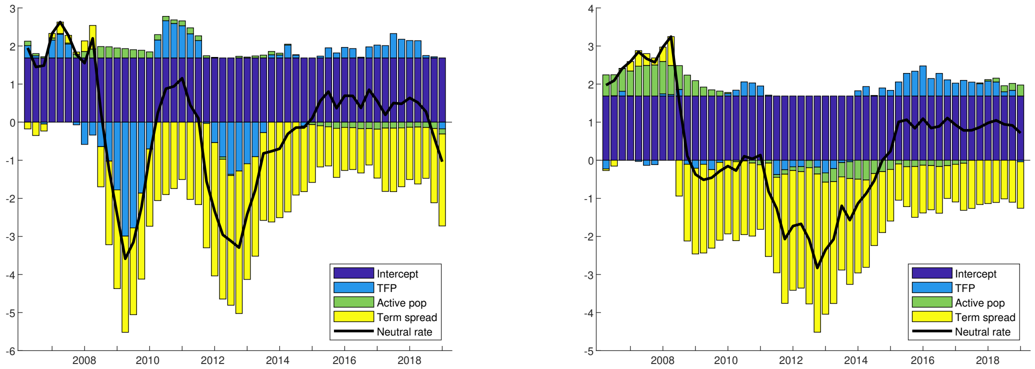
Dep. var. r	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
Constant	0.972***	1.868***	0.933***	1.684***	1.821***	1.556***	0.899***	2.426***	3.892***	4.398***	5.001***	4.221***	5.322***	4.660***	2.766***
TFP growth (YoY)	0.371***	0.433***	0.264***	0.428***				0.377***	0.435***	0.241***	0.401***				
Population growth			0.633***	0.404**		0.567***	0.713***			4.8e-03	-0.190		-0.163	-0.018	
Term premia		-0.689***		-0.638***	-0.594***	-0.538***			-0.676***		-0.586***	-0.602***	-0.511***		
FE	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Time trend	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.03	0.23	0.04	0.22	0.15	0.15	0.03	0.08	0.35	0.26	0.42	0.31	0.41	0.29	0.07
Observations	824	808	773	769	849	809	813	824	808	773	769	849	809	813	865

Table 2: Estimates of long run equation

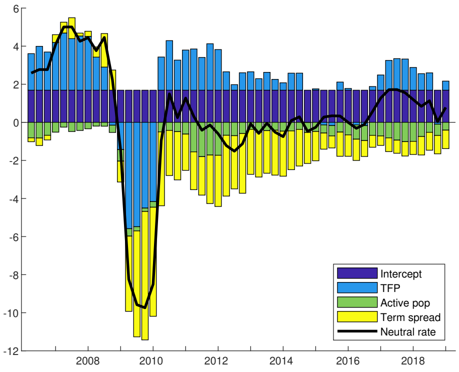
B Drivers behind the changes in r^* across some EA countries



(a) DE **(b)** FR



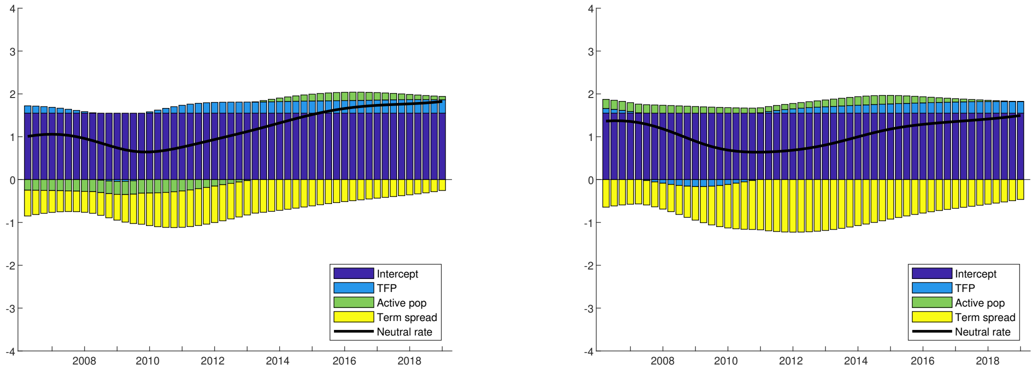
(c) IT **(d)** ES



(e) LT

Figure 8: Drivers behind the changes in r^* across some EA countries (actual data)

Note: Decomposition is calculated using the panel estimates provided in Table 1 column 6



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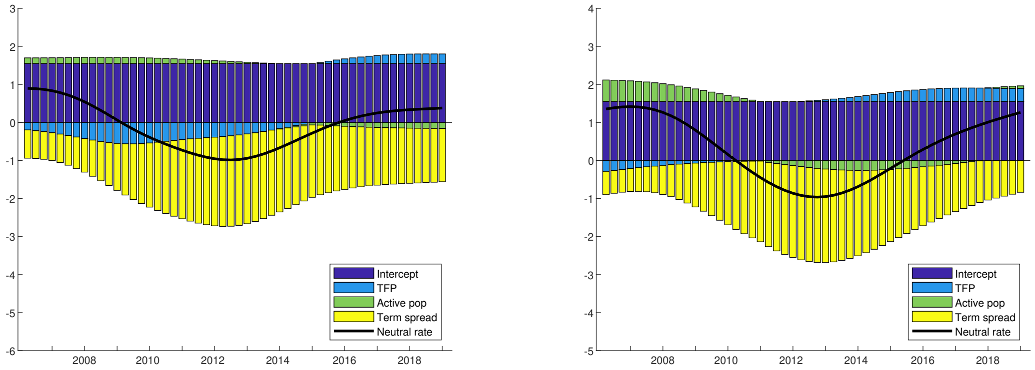

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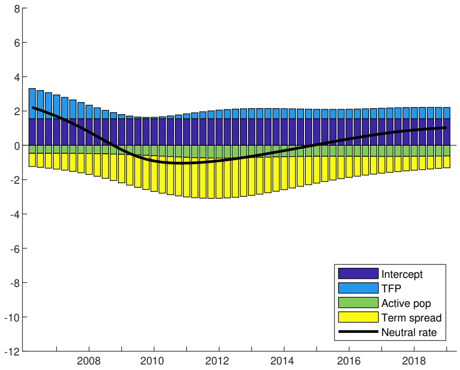
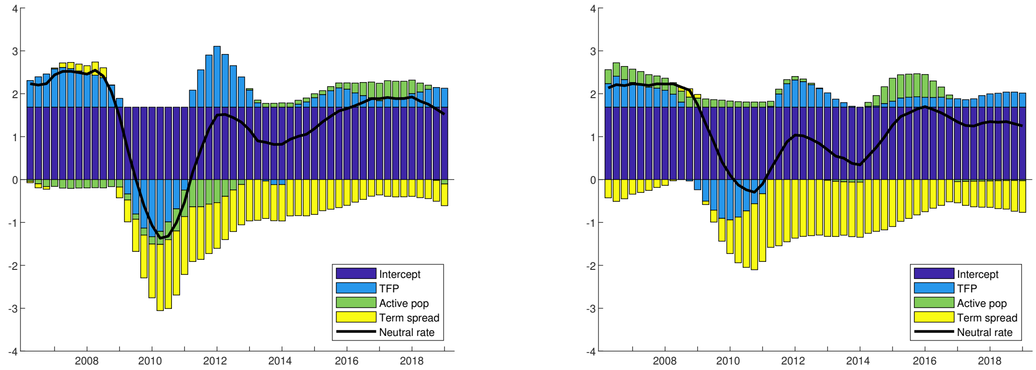


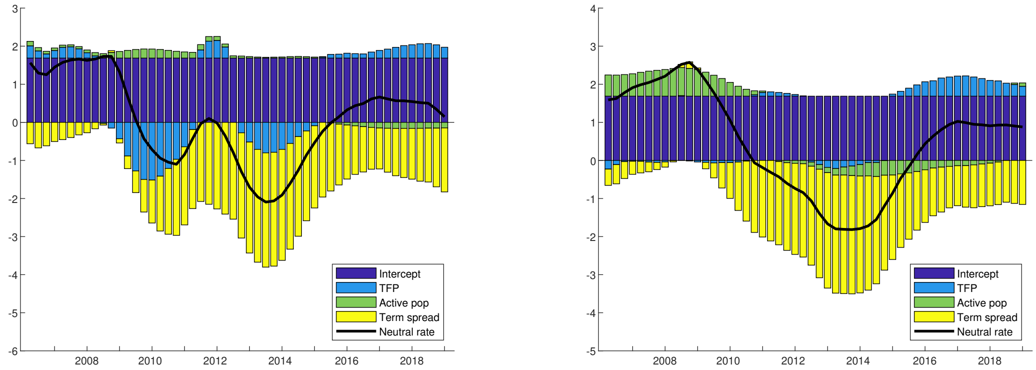
(e) LT

Figure 9: Drivers behind the changes in r^* across some EA countries (trend calculated using Hodrick–Prescott filter)

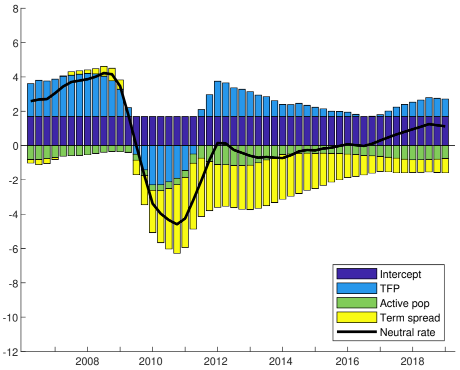
Note: Decomposition is calculated using the panel estimates provided in Table 1 column 6



(a) DE **(b)** FR



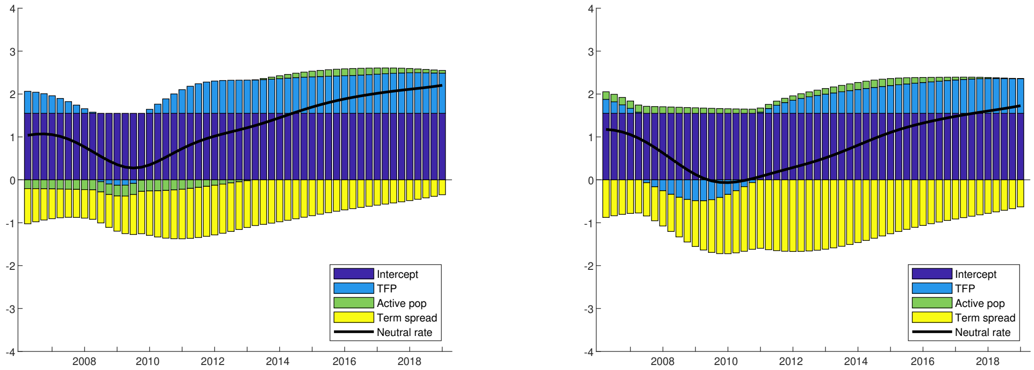
(c) IT **(d)** ES



(e) LT

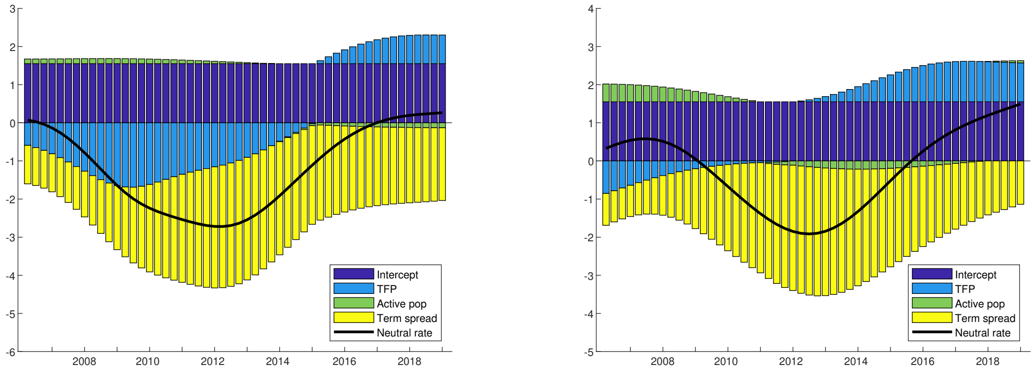
Figure 10: Drivers behind the changes in r^* across some EA countries (trend of 8Q moving average)

Note: Decomposition is calculated using the panel estimates provided in table 1 6^{th} column



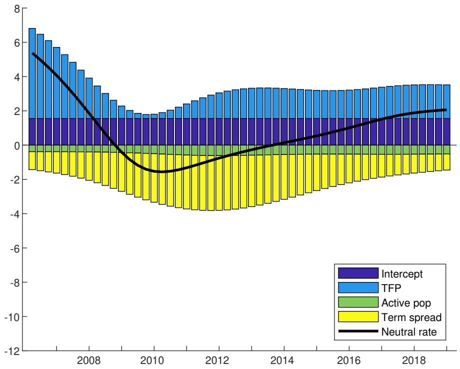
(a) DE

(b) FR



(c) IT

(d) ES



(e) LT

Figure 11: Drivers behind the changes in r^* across some EA countries (trend calculated using Hodrick–Prescott filter)

Note: Decomposition is calculated using the panel estimates provided in table 1 column 9

C Deviations in interest rate gaps vs natural rate of interest

In order to inspect how actual rates compare with natural rates we calculate interest rate gaps. These are driven not only by actual short term rate and natural rates, but also inflation in EA member states. Results show that in major 4 EA economies and Lithuania actual real rates during the GFC have been higher than natural rates (Figure 12). More recently trend reversed and towards 2018 interest rate gaps turned negative.

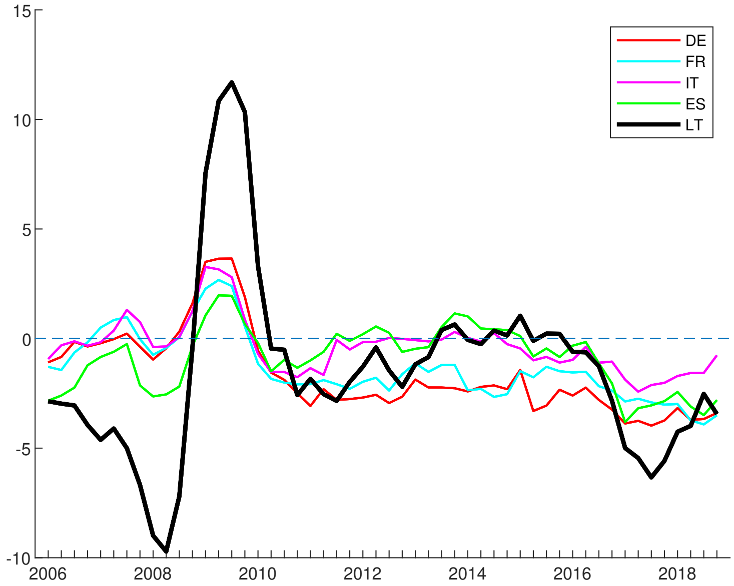


Figure 12: Interest rate gaps across major EA countries and Lithuania

We also observe some variation across countries. Interest rate gap tends to be close to 0 over the whole period in Italy and Spain, but it is mostly negative in Germany and France. As with the natural rate, variation in interest rate gap in Lithuania is much higher than in major EA economies. Strong negative gap is also observable before the GFC implying that actual interest rates have been much lower than the ones driven by fundamentals. Recently interest rate gap in Lithuania turned negative again, but it is not substantially different from major EA economies.

D Inflation expectations and natural rate of interest

Real rate of interest is calculated by formula 9.

$$r_t = i_t - \mathbb{E}_t\{\pi_{t+1}\} \tag{9}$$

where r_t denotes real rate if interest, i_t denotes nominal rate of interest and $\mathbb{E}_t\{\pi_{t+1}\}$ denotes inflation expectations. There are many options how we can model inflation expectations[22]:

Backward looking as in Holston et al. (2017):

$$\mathbb{E}_t\{\pi_{t+1}\} = \frac{\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3}}{4} \tag{10}$$

Simple backward looking:

$$\mathbb{E}_t\{\pi_{t+1}\} = \pi_t \tag{11}$$

Forward looking with perfect foresight:

$$\mathbb{E}_t\{\pi_{t+1}\} = \pi_{t+1} \tag{12}$$

While all aforementioned approaches can have its merits, the results can be driven by this assumption. In fig. 13 we show real interest rate calculated using different assumption about inflation expectations ((10) - (12)). As Lithuania had somewhat high and volatile inflation over the last business cycle, the results depended on this crucial assumption.

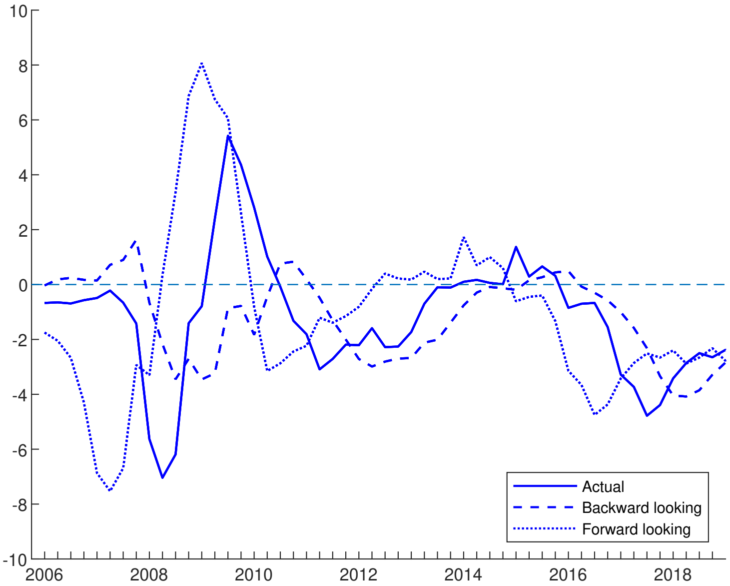


Figure 13: Real rate of interest under different expectations formation in Lithuania

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[22] Another option would be use the market, or professional forecasters inflation expectations, but those are available in just a small subset of countries.