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Dynamics of the natural rate of interest and monetary policy☆

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ABSTRACT

This paper studies the relation between the monetary policy rate and the natural rate of interest in the euro area and the United States across the periods of conventional monetary policy (CMP) and unconventional monetary policy (UMP). The unobserved time series of the natural rate of interest is estimated at the monthly frequency at which the relation between the policy rate and the natural rate is evaluated. The results indicate that the dynamics of the policy rate was positively and significantly related to the variations in the natural rate during the CMP period. The relation twisted during the UMP period.

1. Introduction

When the short-term interest rate approached the zero lower bound (ZLB) during the global financial crisis, that triggered extensive discussions on the dynamics of the natural rate of interest. As Bernanke (2020) points out, the monetary policy space is constrained by the natural rate of interest being close to the ZLB. While there are many discussions on the monetary policy stance benchmarked against the natural rate, there is not much on the actual link between the policy rate and the natural rate. The objective of this paper is to evaluate the link between the monetary policy rate and the natural rate of interest in the euro area (EA) and the United States (US) over the periods of conventional monetary policy (CMP) and unconventional monetary policy (UMP).

When the CMP tool, the short-term interest rate, hit the ZLB, monetary authorities resorted to UMP measures such as forward guidance and quantitative easing to lower the long-term interest rate. This led to various discussions on the potential of the UMP to circumvent the ZLB and the need to raise an inflation target to increase policy space. In the EA and the US, the application of UMP measures was mainly related to the institutional factors of the ECB and the Fed, and their policies in the wake of the ZLB. Consequently, the implementation of UMP was not simultaneous in the EA and the US. It was also related to the ZLB period, which was driven by the dynamics of the natural rate of interest.

Holston et al. (2017) (hereafter HLW) define the natural rate of interest as the real short-term interest rate that would prevail when output is at its natural level and inflation is stable. The natural rate of interest is also called the neutral rate of interest or $r*$. Though these terms are generally used interchangeably, Platzer et al. (2022) distinguish between the natural and the neutral rates, which are closely related.

According to Platzer et al. (2022), the natural rate of interest is the long-run neutral rate while the neutral rate is the short-run real rate in which case monetary policy is neither contractionary nor expansionary. The neutral rate is related to the optimal monetary

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policy rate at which the output gap is closed and inflation is zero. Some economic shocks can affect the neutral rate temporarily and it can have significant short-run fluctuations. This paper mainly focuses on the neutral rate and provides its monthly estimates following the methodology proposed by HLW, who provide widely cited quarterly estimates and use the term of the natural rate of interest. Therefore, in line with HLW and for the comparability of results, this paper generally uses that term.

As argued by Foroni and Marcellino (2017), it is important to evaluate models at the highest possible frequency for more precise estimations. The monetary policy rate and expected inflation are available at the monthly frequency while the HLW estimates of the natural rate are at the quarterly frequency. This paper provides the estimates of the natural rate at the monthly frequency, complementing the work by HLW. The estimates of the natural rate are then used for the evaluation of the relation between the policy rate and the natural rate, also complementing the work by Platzer et al. (2022). The results obtained for this relation indicate that the monthly estimates are more precise than the quarterly estimates. The obtained monthly estimates for this relation tend to be more precise than the results based on quarterly data.

2. Empirical methodology

According to the literature, monetary authorities should keep the real interest rate at the level of the natural rate of interest to close the output gap and stabilize inflation. Correspondingly, the optimal (neutral) monetary policy rate is commonly characterized (for example, by Galesi et al., 2017) as the sum of the natural rate of interest and expected inflation:

$$i_t^n = r_t^n + E_t\{\pi_{t+1}\} \tag{1}$$

where i_t^n is the nominal natural interest rate, r_t^n is the real natural rate of interest, and $E_t\{\pi_{t+1}\}$ is expected inflation. Thus, the real natural rate of interest can serve as a benchmark to determine whether monetary policy expansionary or contractionary depending whether the actual nominal policy rate is lower or higher than $r_t^n + E_t\{\pi_{t+1}\}$.

In practice, the actual nominal interest rate generally deviates from the natural (neutral) rate of interest. It is assumed that these deviations are temporary and stochastic. Hence, to evaluate the link between the actual monetary policy rate and the natural rate of interest over time, the following regression model is considered:

$$i_t = \beta_0 + \beta_1 r_t^n + \beta_2 E_t\{\pi_{t+1}\} + \varepsilon_t \tag{2}$$

where i_t is the actual nominal interest rate, $\beta_{j,s}$ are coefficients,[1] and ε_t is an innovation term, which is assumed to be independent and identically distributed with mean zero and constant variance, $\varepsilon_t \sim IID(0, \sigma^2)$. Given the nature of the independent variables of the model, it is also assumed that they are exogenous. Therefore, the regression model is estimated by the method of ordinary least squares.

The natural rate of interest is not directly observable and it can solely be estimated. For several countries, including the EA and the US, HLW provide its quarterly estimates. The underlying variables of their model, including the nominal interest rate but except for real gross domestic product (GDP), are available at the monthly frequency. To evaluate Eq. (2) more precisely, this paper estimates the monthly series of the natural rate following HLW methodology and based on their code.[2]

This paper estimates the monthly series of the natural rate of interest applying the HLW model specification and only making necessary changes. Main modifications are related to the data application. HLW estimate the natural rate using the Kalman filter. They use quarterly data on real GDP, inflation and the short-term nominal interest rate, and compute inflation expectations as the four-quarter moving average of past inflation. Given that real GDP is not available at the monthly frequency, this paper uses the industrial production index (IPI) instead as an indicator of real economic activity. This paper computes inflation expectations as the twelve-month moving average of past inflation. At the final stage, the monthly estimates of the natural rate are scaled with respect to the HLW quarterly estimates.

3. Data description

This paper uses the estimation period from 1999:M1 to 2008:M09 to estimate the regression model over the CMP period. For the UMP period, this paper uses the estimation samples 2012:M1–2019:M12 and 2008:M10–2016:M12 for the EA and the US, respectively. These samples are specified considering the main periods of the UMP implementation in the EA and the US. At the same time, the monthly series of the natural rate of interest are estimated over the longest possible samples. The series are estimated over the periods 1995:M1–2019:M12 and 1961:M1–2019:M12 for the EA and the US, respectively.

This paper uses the Euribor 3-month rate (available from 1994) and the federal funds effective rate (available from 1955) as a short-term nominal interest rate for the EA and the US, respectively (Fig. 1(a)). They are from the ECB and the Board of Governors of the Fed, respectively. Following HLW, for the estimation of the natural rate before 1965, this paper considers the discount rate of the New York Fed as a short-term rate from the IMF. As a long-term nominal interest rate, this paper uses the 10-year long term government bond yields, which are from the OECD. Fig. 1(b) shows that the long-term rate (LTR) was not at the ZLB and had some variation in the EA and the US after 2008:M09 in contrast to the short-term rate (STR). Actually, the LTR was the main monetary policy instrument of central banks during the ZLB period. Therefore, the STR is considered as a CMP rate while the LTR is treated as an UMP instrument (Fig. 1).

[1] The inclusion of the coefficient β_0 in the model is mainly related to technical reasons. Since r_t^n is not observed and is estimated, β_0 accounts for the potential scale differences between i_t and r_t^n. The inclusion of the intercept also allows considering R^2.

[2] The HLW code and updated quarterly estimates are publicly available on the website of the New York Fed.

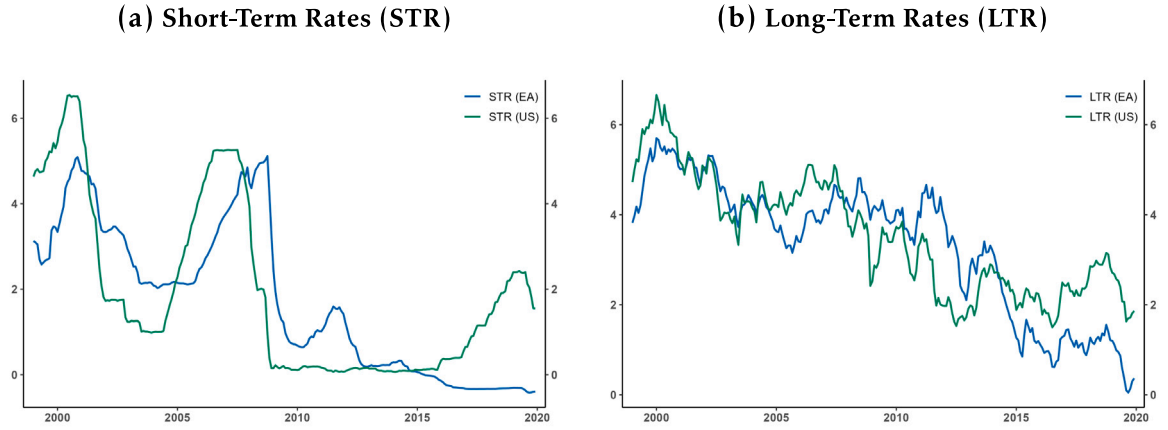

Fig. 1. Monthly short-term and long-term interest rates. *Note:* As a short-term nominal interest rate, the Euribor 3-month rate and federal funds effective rate are considered for the EA and the US, respectively. As a long-term nominal interest rate, 10-year government bond yields are considered for the EA and the US.

For the estimation of the monthly series of the natural rate, this paper uses available actual monthly data for the underlying variables as a baseline approach. The IPI is considered as a baseline indicator of real economic activity. The data on the IPI for the EA and the US are from the OECD and the Board of Governors of the Fed, respectively. Alternatively, the monthly estimates of real GDP are also considered. For the EA, the quarterly series of real GDP, which is from Eurostat, is interpolated into the monthly series using the IPI as a monthly reference series.[3] For the US, S&P Global is the data source for the estimates, which are available from 1992:M1 and so the series of the natural rate is estimated from 1993:M1 (given the twelve-month moving average computation of inflation expectations). As a price index for the EA, this paper uses the harmonized index of consumer prices from the OECD. It is the longest available monthly series of an EA price index (available from 1990). In line with HLW, as a price index for the US, this paper considers the personal consumption expenditures (excluding food and energy) price index from the US Bureau of Economic Analysis.

The inflation expectations for the next period are proxied by the following available monthly series. For the EA, this paper uses consumer opinion surveys about the future tendency (the next twelve months) of consumer prices (in the units of percentage balance) from the OECD. For the US, this paper uses median expected price change (in percent) over next twelve months based on the surveys of consumers from the University of Michigan. As a robustness check, this paper extends the specification of Eq. (2) by also incorporating the composite leading indicator (CLI) as a forwarding-looking variable for real economic activity. The CLI is from OECD and it is expressed in percent changes. The reference series for the CLI is GDP. For the EA, this paper considers the CLI that is normalized for major four European countries. Also, this paper uses the CLI that is normalized for the US.

4. Empirical analysis

The baseline monthly estimates of the natural rate of interest based on the IPI for the EA and the US are presented in Fig. 2. The alternative monthly estimates of the natural rate based on real GDP for the EA and the US are provided in Fig. 3. These estimates of the natural rate have similar patterns. The patterns of the current estimates are also similar to the HLW quarterly estimates. This can be seen if the monthly series are aggregated to the quarterly frequency and they are drawn together with the HLW estimates, as presented in Fig. A.1.

Using the baseline estimates of the natural rate of interest, Eq. (2) is estimated at the monthly frequency. Table 1 contains the estimation results for the EA. For the CMP period, there is a strong positive relation between the monetary policy rate and the natural rate. One percentage point increase in the natural rate raises the policy rate by around 0.9 percentage points. The effect of expected inflation on the policy rate is also significant. It is positive as expected. Around 72 percent of the variation in the policy rate is due to the dynamics of the natural rate and expected inflation. For the UMP period, the relation between the monetary policy rate and the natural rate becomes negative, and R^2 is nearly twice lower. Over that period, while the natural rate was increasing after hitting the ZLB, the LTR had a declining trend reflecting conducted UMP measures, which are more multidimensional and are not strongly linked with the dynamics of the natural rate.

Table 2 reports the estimation results for the US. For the CMP period, the relation between the monetary policy rate and the natural rate is positive and significant as in the case of the EA but the coefficient is larger. One percentage point increase in the natural rate raises the policy rate by about 1.4 percentage points. The impact of expected inflation on the natural rate is positive and significant as previously. The natural rate and expected inflation account for around 46 percent of the variation in the monetary

[3] The interpolation is implemented using the software Ecotrim developed by Eurostat.

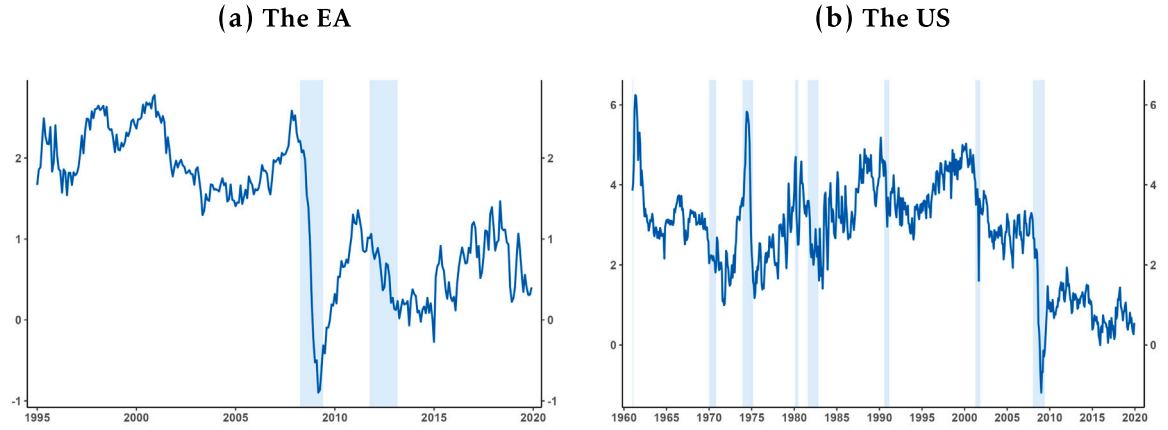

Fig. 2. Monthly Estimates of the Natural Interest Rate. *Note:* The figures display the monthly estimates of the natural rate of interest (estimated based on the IPI) for the EA and the US over the periods 1995:M1–2019:M12 and 1961:M1–2019:M12, respectively.

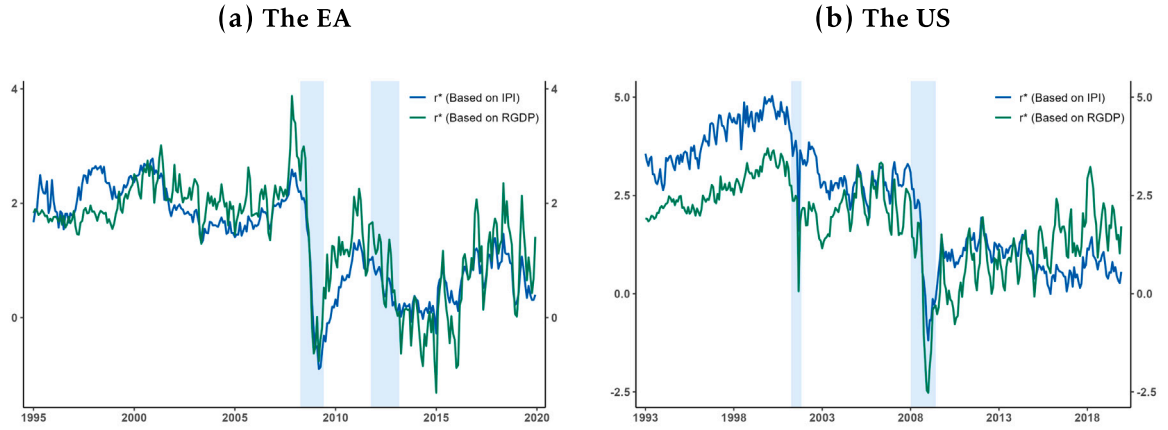

Fig. 3. Alternative monthly estimates of the natural interest rate. *Note:* The figures display the monthly estimates of the natural rate of interest based on the IPI and real GDP (RGDP) for the EA and the US over the periods 1995:M1–2019:M12 and 1993:M1–2019:M12, respectively.

Table 1
Monthly parameter estimates of the model for the EA.

	CMP period (1999:M1–2008:M9)	UMP period (2012:M1–2019:M12)
	Short-term interest rate	Long-term interest rate
Natural interest rate	0.888***	−1.080***
	(0.175)	(0.212)
Expected inflation	0.067***	0.064***
	(0.008)	(0.010)
Constant	0.109	1.210***
	(0.266)	(0.213)
N	117	96
R^2	0.716	0.375
F Statistic	143.421***	27.880***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated at the monthly frequency using the baseline estimates of the natural interest rate.

policy rate. R^2 is lower than it is in the case of the EA. For the UMP period, the effect of the natural rate on the policy rate is negative as for the EA because of the reasons mentioned above. At the same time, it is smaller and R^2 is close to zero in this case. The differences in the magnitudes of the coefficients are related to the dynamics of the natural rate and monetary policy design specific to the EA and the US. Yet, the results highlight their common relation across the policy periods.

Table 2
Monthly parameter estimates of the model for the US.

	CMP period (1999:M1–2008:M9)	UMP period (2008:M10–2016:M12)
	Short-term interest rate	Long-term interest rate
Natural interest rate	1.436***	−0.271*
	(0.150)	(0.153)
Expected Inflation	0.940***	0.415**
	(0.193)	(0.183)
Constant	−4.023***	1.514***
	(0.880)	(0.471)
N	117	99
R^2	0.455	0.052
F Statistic	47.612***	2.649*

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated at the monthly frequency using the baseline estimates of the natural interest rate.

For comparison, Eq. (2) is also estimated at the quarterly frequency using the HLW estimates for the natural rate. The results are provided in Tables A.1 and A.2. As a result of the aggregation, the variables are considered at the lower frequency and the estimation samples get shorter. Consequently, the estimates become imprecise. While the effect of the natural rate on the monetary policy rate is positive for the EA and the US over the CMP period, it is not significant in the case of the EA and it is almost twice larger than the coefficient in the case of the US. For the UMP period, the results for the EA show that the impact of the natural rate on the policy rate is still negative but it becomes insignificant. The results for the US indicate that the natural rate has a positive significant effect on the policy rate, and the impact of expected inflation the policy rate is negative and insignificant in contrast to the baseline results. Various robustness checks of the baseline estimation results are conducted. The baseline monthly and the HLW quarterly estimates of the natural rate of interest for the US are available over longer CMP periods than the estimation samples used to obtain the aforementioned results. Therefore, this paper alternatively considers the CMP period from the beginning of the Great Moderation and provides the estimation results in Table A.3. These estimates are similar to the previous results.

Eq. (2) is estimated with the estimates of the natural interest rate based on real GDP instead of the IPI. Tables A.4 and A.5 show that the results are in line with the baseline estimates. The specification of Eq. (2) is extended with the CLI as a forwarding-looking variable for real economic activity. As can be seen from Tables A.6 and A.7, the baseline estimates of the coefficients of the natural interest rate and expected inflation do not change much. In addition, the STR is replaced by the LTR as a monetary policy rate for the CMP period in the specification of Eq. (2). The results provided in Table A.8 indicate that the impact of the natural rate on the policy rate is still positive for the CMP period.

5. Conclusion

This paper analyzes the relation between the monetary policy rate and the natural rate of interest for the EA and the US over the CMP and the UMP periods. Following the HLW methodology, the monthly series of the natural rate is estimated, and the relation between the policy rate and the natural rate is evaluated at the monthly frequency. The results show that the dynamics of the policy rate was positively and significantly related to the changes in the natural rate during the CMP period. In contrast, during the UMP period, the relation turned to be of the opposite sign. While the natural rate was increasing after approaching the ZLB, the policy rate had a declining trend reflecting implemented UMP measures. Thus, the UMP could counteract the ZLB without the increase in an inflation target.

Declaration of competing interest

The author has no competing interests to declare.

Appendix

See Fig. A.1 and Tables A.1–A.8.

Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.frl.2024.106475.

Data availability

Data will be made available on request.

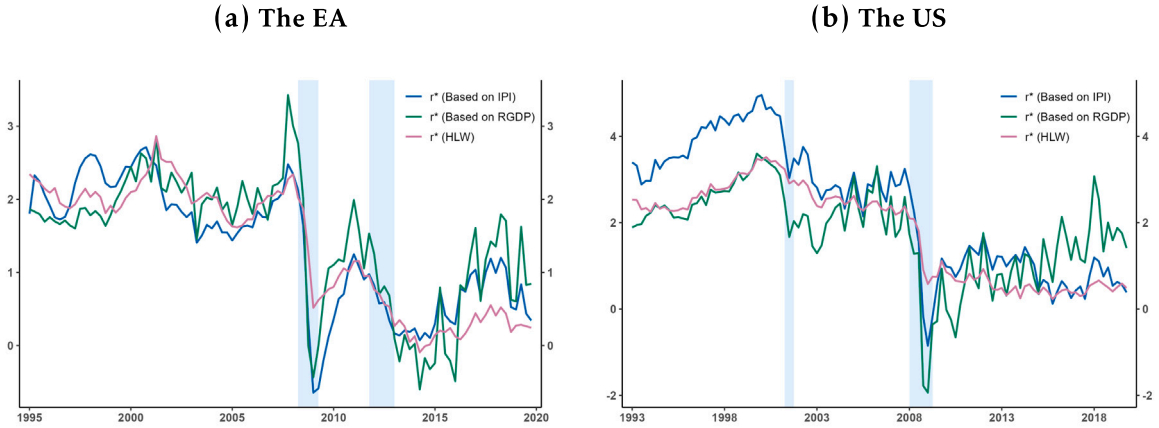

Fig. A.1. Current and HLW quarterly estimates of the natural interest rate. *Note:* The figures display the aggregated quarterly series of the current monthly estimates of the natural rate of interest based on the IPI and real GDP (RGDP), and the HLW series of the natural rate of interest for the EA and the US over the periods 1995:Q1–2019:Q4 and 1993:Q1–2019:Q4, respectively. The monthly series are aggregated to the quarterly frequency by averaging them out.

Table A.1
Quarterly parameter estimates of the model for the EA.

	CMP period (1999:Q1–2008:Q3)	UMP period (2012:Q1–2019:Q4)
	Short-term interest rate	Long-term interest rate
Natural Interest Rate	0.623	−0.793
	(0.399)	(1.056)
Expected Inflation	0.087***	0.072**
	(0.013)	(0.028)
Constant	0.116	0.704*
	(0.690)	(0.383)
N	39	32
R^2	0.717	0.225
F Statistic	45.512***	4.222**

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated at the quarterly frequency using the HLW estimates for the natural interest rate.

Table A.2
Quarterly parameter estimates of the model for the US.

	CMP period (1999:Q1–2008:Q3)	UMP period (2008:Q4–2016:Q4)
	Short-term interest rate	Long-term interest rate
Natural Interest Rate	2.615***	1.808***
	(0.606)	(0.450)
Expected Inflation	1.271***	−0.043
	(0.425)	(0.228)
Constant	−7.337***	1.600**
	(2.504)	(0.679)
N	39	33
R^2	0.356	0.356
F Statistic	9.933***	8.277***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated at the quarterly frequency using the HLW estimates for the natural interest rate.

Table A.3
Monthly and quarterly parameter estimates of the model based on longer CMP periods for the US.

	Monthly	Quarterly
	CMP period (1985:M1–2008:M9)	CMP period (1985:Q1–2008:Q3)
	Short-term interest rate	Short-term interest rate
Natural Interest Rate	1.638***	3.045***
	(0.129)	(0.324)
Expected Inflation	1.435***	1.309***
	(0.166)	(0.273)
Constant	−5.257***	−7.683***
	(0.712)	(1.213)
N	285	95
R^2	0.445	0.563
F Statistic	112.829***	59.151***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The monthly and the quarterly parameter estimates of the regression model are based on longer CMP periods for the US.

Table A.4
Alternative monthly parameter estimates of the model for the EA.

	CMP period (1999:M1–2008:M9)	UMP period (2012:M1–2019:M12)
	Short-term interest rate	Long-term interest rate
Natural Interest Rate	0.406***	−0.679***
	(0.154)	(0.103)
Expected Inflation	0.082***	0.084***
	(0.008)	(0.010)
Constant	0.623**	0.675***
	(0.285)	(0.179)
N	117	96
R^2	0.672	0.455
F Statistic	116.593***	38.819***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated using the estimates of the natural interest rate based on real GDP.

Table A.5
Alternative monthly parameter estimates of the model for the US.

	CMP period (1999:M1–2008:M9)	UMP period (2008:M10–2016:M12)
	Short-term interest rate	Long-term interest rate
Natural interest rate	1.552***	−0.351***
	(0.179)	(0.065)
Expected inflation	0.518***	0.405***
	(0.192)	(0.128)
Constant	−1.721**	1.525***
	(0.760)	(0.374)
N	117	99
R^2	0.407	0.250
F Statistic	39.101***	15.959***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated using the estimates of the natural interest rate based on real GDP.

Table A.6
Monthly parameter estimates of the extended model for the EA.

	CMP period (1999:M1–2008:M9)	UMP period (2012:M1–2019:M12)
	Short-term interest rate	Long-term interest rate
Natural interest rate	1.192***	−1.094***
	(0.161)	(0.214)
Expected inflation	0.055***	0.066***
	(0.007)	(0.011)
Composite leading indicator	−2.308***	0.866
	(0.381)	(1.414)
Constant	−0.201	1.186***
	(0.238)	(0.217)
N	117	96
R^2	0.785	0.377
F Statistic	137.890***	18.587***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is extended with the composite leading indicator, which is in percent changes.

Table A.7
Monthly parameter estimates of the extended model for the US.

	CMP period (1999:M1–2008:M9)	UMP period (2012:M1–2019:M12)
	Short-term interest rate	Long-term interest rate
Natural interest rate	1.439***	−0.622***
	(0.151)	(0.212)
Expected inflation	0.960***	0.623***
	(0.200)	(0.200)
Composite leading indicator	0.473	1.668**
	(1.184)	(0.715)
Constant	−4.091***	1.203**
	(0.900)	(0.479)
N	117	96
R^2	0.456	0.104
F Statistic	31.561***	3.661**

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is extended with the composite leading indicator, which is in percent changes.

Table A.8
Monthly parameter estimates of the model with the LTR for the CMP period.

	EA	US
	CMP period (1999:M1–2008:M9)	CMP period (1999:M1–2008:M9)
	Long-term interest rate	Long-term interest rate
Natural interest rate	1.124***	0.713***
	(0.148)	(0.047)
Expected inflation	0.002	0.125**
	(0.007)	(0.060)
Constant	2.180***	2.018***
	(0.224)	(0.273)
N	117	117
R^2	0.497	0.681
F Statistic	56.419***	121.584***

Notes: Standard errors are in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01. The regression model is estimated with the long-term rate (LTR) instead of the short-term rate (STR) for the CMP period (1999:M1–2008:M9).

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