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Forecasting inflation with a zero lower bound or negative interest rates: Evidence from point and density forecasts

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Abstract

This paper investigates the predictive power of the shadow rate for the inflation rate in countries with a zero lower bound (the US, the UK and Canada) and in those with negative rates (Japan, the Euro Area and Switzerland). Using shadow rates obtained from two different models (the WX(3) and the KANSM(2) ones) and for different LB parameters we compare the out-of-sample forecasting performance of an inflation model including a shadow rate with a benchmark one excluding it. Both specifications are estimated by OLS (Ordinary Least Squares) and includes a range of macroeconomic factors computed by means of principal component analysis. Both point and density forecasts of the inflation rate are evaluated. The models including the shadow rate are found to outperform the benchmark ones according to both sets of criteria except in countries operating an official inflation targeting regime. Both types of shadow rates appear to produce equally accurate out-of-sample inflation forecasts.

KEYWORDS
density forecasts, inflation forecasting, shadow interest rates, zero lower bound

JEL CLASSIFICATION
C38, C53, E37, E43, E58

1 | INTRODUCTION

As a result of the 2007–2008 global financial crisis a number of central banks had to adopt unconventional monetary policy measures to support the functioning of financial markets; such a situation has arisen again during the current Covid-19 pandemic and is characterised by the so-called zero lower bound (ZLB) occurring when the short-term nominal interest rate is at or near zero, which causes a liquidity trap and limits the ability of monetary authorities to stimulate economic growth. An important question arising in this context is how the monetary policy stance can be accurately measured in periods when the policy rate is close to the ZLB or even negative.

The literature has addressed this issue by introducing the concept of the shadow policy rate, which is constructed using interest rates at longer maturities and is not constrained by the ZLB. The standard approach to estimate the shadow rate during periods of unconventional monetary policy is based on term structure models including different numbers of factors (Krippner, 2015a; Wu & Xia, 2016); during non-ZLB times, the shadow rate is the same as the policy rate. Previous research has assessed how well this measure captures the monetary policy stance (Ichiue & Ueno, 2018; Ristiniemi and de Rezende, 2018) and how closely it tracks the official policy rate (Krippner, 2015b; Lombardi & Zhu, 2014). However, most of the existing studies have not analysed the issue of whether the shadow rate is a more accurate predictor of the inflation rate than the official policy rate during ZLB periods, the only exceptions being the contributions by Kuusela and Hännikäinen (2017) and Hännikäinen (2017), who focussed on the US case.

This paper aims to provide more extensive evidence on the predictive power of shadow rates for inflation by constructing them using two different types of models, namely the Wu and Xia (2016) three-factor term structure model and the Krippner (2015a) arbitrage-free two state-variable model which follows Nelson and Siegel (1987). More precisely, we assess both the in-sample and out-of-sample performance of a forecasting model capturing the effects of the ZLB environment on the relationship between interest rates and inflation with a benchmark one which does not take it into account. The analysis is conducted for two sets of countries, the first comprising the US, the UK and Canada, where interest rates were near or at zero, and the second Japan, the Euro Area and Switzerland, where rates were lowered below zero. Moreover, both point and density forecasts are considered; the latter provide information about the uncertainty around inflation forecasts by attaching a probability to the different possible outcomes for future inflation and are increasingly used by both central banks and researchers. In both respects (country coverage and forecast density evaluation) the present study extends significantly the work of Kuusela and Hännikäinen (2017) and Hännikäinen (2017) and thus sheds additional light on the issues of interest.

The remainder of the paper is structured as follows: Section 2 briefly reviews the relevant literature; Section 3 outlines the econometric models used for the analysis; Section 4 discusses the data and the empirical results; Section 5 offers some concluding remarks.

2 | LITERATURE REVIEW

The literature on inflation forecasting is extensive and it uses a variety of approaches including ARIMA models (Junttila, 2001; Salisu & Isah, 2018), factor models and principal component analysis (Inoue & Kilian, 2008; Kunovac, 2007; Mehrotra & Sánchez-Fung, 2008; Poncela & Senra, 2006), and dynamic panel models (Boero et al., 2008; Döpke et al., 2019). The forecasting performance of these alternative models has been assessed by several studies. Ang et al. (2007), for instance, reported that surveys produce more accurate inflation forecasts for the US compared

to the Phillips curve and term structure models. Lee (2012) found that the ARIMA model outperforms a Phillips curve and a naïve model in terms of out-of-sample forecasting in a group of 26 inflation targeting countries. In their overview of the literature Faust and Wright (2013) concluded that survey forecasts generally outperform model-based forecasts. The latter have considered a variety of possible determinants of inflation, including past inflation (Ball and Cecchetti, 1990; Bollerslev, 1986), economic activity variables such as unemployment and output (Atkeson & Ohanian, 2001; Canova, 2007; Orphanides & Van Norden, 2005), and inflation expectations (Berge, 2018; Chan et al., 2018).

Numerous studies have reported that more accurate inflation forecasts are obtained by carrying out principal component analysis. For instance, Forni et al. (2003) showed that a dynamic panel principal components model including a set of financial variables (nominal and real interest rates and exchange rates) provides better inflation forecasts for the Euro-Area countries than a univariate AR model without those variables. Eickmeier and Ziegler (2008) also argued that factor models generally outperform others in terms of predictive power for inflation, but there is some variation depending on the country under examination and the size of the dataset used to extract the factors.

More recently, density forecasts have been considered in addition to point forecasts of inflation. In particular, Lahiri and Liu (2006) analysed a heterogeneous panel of density forecasts from the Survey of Professional Forecasters and concluded that inflation forecast uncertainty in the US varies according to the inflation level but is less persistent than suggested by the data, which can produce misleading results when ignoring forecaster heterogeneity that can affect the dynamics of uncertainty. When examining matched point and density forecasts from the same survey using seemingly unrelated regressions, Rich and Tracy (2010) found mixed evidence on whether increases in expected inflation are related to greater uncertainty, but documented a strong positive relationship between expected inflation and the dispersion of inflation point forecasts. Groen et al. (2013) evaluated point and density forecasts of US inflation using Bayesian model averaging and showed that both are highly accurate when allowing for a large number of predictors and structural breaks in the model. Gaglianone and Lima (2014) obtained density forecasts of US inflation by combining point forecasts when the decision-maker has limited information about the underlying model, and found that their approach improves the real-time accuracy of density forecasts. Alessandri and Mumtaz (2017) estimated linear and nonlinear VAR models and showed that the inclusion of financial variables improves both point and density forecasts of US inflation. Finally, Hall and Mitchell (2007) argued that combining point and density forecasts improves predictions of UK inflation, though this depends on the weights assigned to the latter.

Obtaining accurate inflation forecasts is crucial for central banks, but forecasting models have normally been based on the official policy rate (Forni et al., 2003; Monteforte & Moretti, 2013), which is not informative about the monetary policy stance at times when the interest rate is near or at zero. This issue is addressed in a recent paper by Kuusela and Hännikäinen (2017), who assess the predictive power of the shadow policy rate for US inflation by means of an h-step-ahead factor model. More precisely, 14 shadow rates are computed from both a shadow rate term-structure model (Wu & Xia, 2016) and an arbitrage-free two state-variable model (Krippner, 2015a) which follows Nelson and Siegel (1987). The former are found to outperform the latter in terms of inflation forecasting accuracy, with the shadow policy rate providing valuable information about future inflation. Similar results were also obtained by Hännikäinen (2017). As already mentioned, the present study extends this type of analysis by considering a wider set of countries as well as both point and density forecasts.

3 | EMPIRICAL FRAMEWORK

3.1 | A shadow rate forecasting model of inflation

We estimate the following linear h-step-ahead factor model as in Kuusela and Hännikäinen (2017):

$$\pi_{t+h}^{h} = \alpha_h + \sum_{j=1}^{m}\sum_{i=1}^{k} \beta_{hij}\hat{F}_{i,t-j+1} + \sum_{j=1}^{p} \gamma_{hj}\pi_{t-j+1} + \varphi_h z_t + u_{t+h}^{h} \tag{1}$$

where π_{t+h}^{h} is the h-step-ahead inflation rate which is computed using the Consumer Price Index (CPI), $\hat{F}_{i,t}$ is the ith principal component constructed from a large dataset of macroeconomic variables,[1] π_{t-j+1} are past lags of the inflation rate, z_t is the shadow rate which is computed either as in Wu and Xia (2016) or as in Krippner (2015a), and u_{t+h}^{h} is the forecast error term. To assess whether the predictive power of the shadow rate differs between the ZLB and the non-ZLB periods, we also estimate the following forecasting regression:

$$\begin{aligned}\pi_{t+h}^{h} = \alpha_h + \sum_{j=1}^{m}\sum_{i=1}^{k} \beta_{hij}\hat{F}_{i,t-j+1} + \sum_{j=1}^{p} \gamma_{hj}\pi_{t-j+1} + \\ +\varphi_h z_t + \psi_h(ZLB_t * z_t) + u_{t+h}^{h}\end{aligned} \tag{2}$$

where ZLB_t is a dummy variable which is equal to 1 when the policy rate is at the ZLB and to 0 otherwise.[2] The ZLB dummy interacts with the shadow rate z_t; a significant interaction coefficient ψ_h indicates that the relationship between the shadow rate and the inflation rate differs between ZLB and non-ZLB periods.

The factors $\hat{F}_{i,t}$ can be estimated by principal component analysis, which parsimoniously reduces the dimensionality of large datasets into a few latent factors without losing too much information. However, standard principal component analysis which uses large sets of data can suffer from cross-correlation of the idiosyncratic errors and therefore the extracted factors can be less useful for forecasting (Bai & Ng, 2008). To address this issue, Boivin and Ng (2006) suggest to use weighted principal component analysis in which each series is weighted according to some weight selection criterion. In this paper, we apply the lasso-based elastic net method which allows us to use elastic net estimates to define a weight for each variable with non-zero coefficients in the principal component analysis (Fosten, 2017). Using this approach should make our factor analysis more robust to autocorrelation in the idiosyncratic error term.

The identified factors can be useful predictors in forecasting exercises. In the existing literature, factor models have been found to produce more accurate macroeconomic forecasts than rival specifications (Bernanke & Boivin, 2003). The forecasting horizons we consider are $h = 3, 6, 9, 12$ months and the estimation is carried out using OLS. The number of factors and lags is determined using the Bayesian-Schwarz information criterion for a range from 1 to 6 factors.

3.2 | Shadow policy rate estimation

As already mentioned, we follow two approaches to estimate the shadow policy rates for the countries under examination. One is the three-factor term-structure model of Wu and Xia (2016) (WX(3)) and the

[1]Details of the variables included in the large dataset and their sources for all countries in our sample can be found in Appendix C.

[2]More precisely, we define as ZLB periods those during which the interest rate had a value of 25 basis points or lower.

other is the Krippner (2015a) two-factor arbitrage-free Nelson and Siegel (1987) model (K-ANSM(2)). Both methods use longer-term interest rates to construct the shadow rates from term-structure models.

The forward rate in the WX(3) shadow rate model can be approximated by the following state space representation form:

$$f^{o}_{n,n+1,t} = \underline{r} + \sigma^{Q}_{n} g\left(\frac{a_n + b'_n X_t - \underline{r}}{\sigma^{Q}_{n}}\right) + \eta_{nt} \tag{3}$$

where $\underline{r}$ is the LB, $\left(\sigma^{Q}_{n}\right)^2$ is the conditional variance of the future shadow rate, X_t are the state variables in a first order Vector Autoregressive (VAR(1)) model and $a_n + b'_n X_t$ is the n-period forward rate from a Gaussian affine term structure model.[3] The WX(3) model assumes the shadow rate to be a linear function of three latent factors X_t, which represent its level, slope and curvature respectively and are estimated by using the extended Kalman filter (Wu & Xia, 2017).

The forward rate in the KANSM(2) shadow rate model can be computed as follows:

$$f(x_t, \tau) = L_t + S_t \cdot \exp\left(-\tilde{\phi}\tau\right) + VE(\tau) \tag{4}$$

where x_t is a vector of state variables, $\tilde{\phi}$ defines the risk-adjusted mean-reversion matrix, τ is the time to maturity and $VE(\tau)$ is a term which allows for the effect of the shadow short-rate volatility (namely, the estimated conditional expectation) on expected returns from the shadow yield curve. The shadow short rate is given by $s_t = L_t + S_t$ which uses the two-factor ANSM with level L_t and slope S_t. The related lower-bound forward rate function is the following:

$$\begin{aligned}\underline{f}(x_t, \tau) = r_{LB} \cdot \{1 - \Phi[z(t,\tau)]\} + \omega(\tau) \cdot \phi[z(t,\tau)] + \Phi[z(t,\tau)] \cdot VE(j) + L_t \cdot \Phi[z(t,j)] \\ + S_t \cdot \exp\left(-\tilde{\phi}\tau\right)\Phi[z(t,j)]\end{aligned} \tag{5}$$

where r_{LB} is the lower-bound parameter, $\Phi[\cdot]$ is the cumulative unit normal probability density function, $\phi[\cdot]$ is the unit normal probability density function, $\omega(\tau)$ is the volatility function, $z(t,\tau)$ is the forward rate option effect and j denotes the time to maturity τ expressed in months. The two-factor ANSM provides the most parsimonious approximation to any general GATSM. Similarly to the WX(3) model, the shadow rate in the KANSM(2) model can be estimated with the extended Kalman filter, but Krippner (2016) suggests to use instead the iterated extended Kalman filter, which is more reliable.

3.3 | Density forecasts and robustness checks

The estimate of some future realisation of variable $Y_{T+h|T}$, based on the available information set X_T, can be denoted as $\hat{Y}_{T+h|T}$ and is the h-step ahead point forecast of Y_{T+h}. Point forecasts are commonly used to obtain an estimate of the future outcomes of a variable of interest (Timmerman, 2000). Density forecasts instead provide an estimate of the conditional distribution $f(Y_{T+h}|X_T)$, which attaches a probability to all possible values of the outcome variable—they are included in our analysis to estimate the uncertainty around inflation predictions.

We obtain in-sample predictions for the entire sample period by using the forecasting regression models (1) and (2), while for evaluating the out-of-sample forecasting performance we consider model (1) only in the same way as Hännikäinen (2017) does for the US to make our results directly comparable

[3]For a full derivation of a_n and b'_n, see Wu and Xia (2016).

with theirs. By dropping the shadow rate one can obtain a benchmark model and then compare the forecasting performance of the two specifications and thus assess the marginal predictive power of the shadow rate. The forecasting accuracy of the model including the shadow rate is compared to that of a benchmark specification without it. More specifically, we use a recursive forecasting scheme and compute the mean squared prediction errors (MSPEs) of the h-step-ahead forecasts with real-time data for both models, where a lower MSPE indicates a better forecasting performance. The forecasting performance of the model including the shadow rate vis-à-vis the benchmark one is made using the one-sided Diebold and Mariano (2002) test with the small sample modification by Harvey et al. (1997). Under the null hypothesis, the mean of the loss differential of the benchmark model is lower or equal to that of the shadow rate model, whilst under the alternative the forecasts of the model including the shadow rate are significantly more accurate than those of the benchmark model. We use the same test to compare the performance of the model with the WX(3) shadow rate with that of the one with the KANSM(2) rate.

For the density forecasts, we employ the circular block bootstrap which wraps the data around a circle before blocking them into fixed length blocks. More precisely, we generate 1000 new time series by resampling with replacement to produce the quantiles of the empirical probability density distribution. The circular block bootstrap has the advantage to be centred around the mean automatically and therefore the distribution is unbiased (Politis & Romano, 1992). We use the continuous ranked probability score (CRPS) to assess the density forecasts of the model with the shadow rate vis-à-vis the benchmark one. The CRPS evaluates the average absolute distance of the empirical cumulative distribution function of the h-step ahead function from that of the predictive density of the model:

$$\mathrm{CRPS}(t+h,l) = \int_{-\infty}^{\infty} (F(z) - I\{y_{t+h} \leq z\})^2 dz$$

where F is the cumulative distribution function from the predictive density of the model with the shadow rate estimated at time t and $I(\cdot)$ takes a value of 1 if $y_{t+h} \leq z$ and a value of 0 otherwise. We compute the ratio of the CRPS of the model with the shadow rate to that of the benchmark one, where a value smaller than 1 indicates that the former outperforms the latter. We also make a direct comparison between the WX(3) and the KANSM(2) shadow rates. In addition, we use the Kolmogorov-Smirnov test of uniformity of the probability integral transform to assess if the empirical cumulative distribution function is significantly different from the theoretical uniform one (Manzan & Zerom, 2008). The one-sided test aims to ascertain whether the forecast with the lower error according to the loss function also exhibits a stochastically smaller error than forecasts from a competing model. In our case, a rejection of the null implies that the density forecast performance of the shadow rate model is significantly superior to that of the benchmark model (Hassani & Silva, 2015).

It is noteworthy that shadow rates can be sensitive to the selection of the LB parameter values. Therefore, we use four different LB values to assess the robustness of the results, namely 0, 14, 19 and 25 basis points for the WX(3) shadow rate and 0, 14, 16 and 25 basis points for the KANSM(2) rate as in Kuusela and Hännikäinen (2017).

4 | DATA AND EMPIRICAL RESULTS

4.1 | Data description

We analyse monthly data for the US, the UK, and Canada, namely countries with a LB of zero or slightly above it, and also for Japan, the Euro Area and Switzerland, where rates were negative. The

sample ends in December 2021 in all cases, whilst the start date differs across countries depending on data availability (see Appendix A for details). The inflation rates are computed as the annual percentage growth of the CPI series from the OECD database.

For the Wu and Xia (2016) shadow rate, the forward rates are constructed using the Nelson-Siegel-Svensson yield curve parameters for maturities of 0.25, 0.5, 1, 2, 5, 7 and 10 years and end-of-the-month observations. For the Krippner (2015a) shadow rate, the maturities used are 1, 2, 3, 5, 7 and 10 years. For the US, the data are taken from the Gürkaynak et al. (2007) dataset which has been updated to 2021. We also obtained from the Federal Reserve Bank of St Louis the Treasury bill rates with 3-month and 6-month maturity, which are used to construct continuously compounding rates for the short end of the yield curve. Forward rate data for the same maturities as above are taken from the Bank of England and the Bank of Canada yield curve datasets for the UK and Canada respectively. For Japan, bond yield and Treasury bill data are obtained from the Japanese Ministry of Finance Government Bond dataset. For the Euro Area the series are the historical Euro Bond Yield data from 1999 onwards taken from the Eurostat economic database. For Switzerland, the data source is the Yields on Bond Issues dataset from the Swiss National Bank Interest Rate Publication database. For all countries except the US we estimate the yield curve parameters empirically by using the model developed by Svensson (1994), which is an extension of the Nelson-Siegel (1987) one.[4] The central bank policy rates for all countries are taken from the Bank for International Settlements database.

The data for the principal component analysis includes a range of macroeconomic variables, namely: (1) real activity and employment variables, (2) monetary and financial variables and (3) price- and inflation-related variables. Details of these variables and their sources for all countries can be found in Appendix C. For the US, the ZLB period goes from January 2009 to December 2015 and then from March 2020 to December 2021. For all other countries, the ZLB period is defined as any period during which the interest rate was at or below 25 basis points.[5] During non-ZLB periods the shadow rate takes on the same values as the official monetary policy rate.

4.2 | Shadow policy rates

Figure 1 plots the WX(3) and KANSM(2) shadow rates with different LB parameters for the entire sample period for the US. The shadow rates seem to track the Federal Funds rate closely during non-ZLB times, but the choice of the LB parameter seems to influence strongly the behaviour of the shadow rate during the ZLB periods, which is consistent with the findings of Kuusela and Hännikäinen (2017). Figures 2–6 plot the shadow rates for the other countries in our sample. During non-ZLB times, these track the central bank policy rates very closely in the Euro Area and Canada, and relatively closely in the UK and Switzerland, but not at all in Japan. During ZLB times they seem to be sensitive to the choice of the LB parameter, especially in the case of the WX(3) rates. As one would have expected, both types of rates became negative for all countries during the recent Covid-19 pandemic.

The graphs above highlight the previously mentioned sensitivity of the estimated shadow rates to the choice of the LB parameter. Bauer and Rudebusch (2016) suggest that this arises from an interaction of the selected LB parameter with short-term yields, which can still exhibit some variation even at near-zero levels owing to idiosyncratic risk in the money markets. In addition, the LB parameter itself is only partially informative about the monetary policy stance. For these reasons, in the following

[4]A detailed description of the model can be found in Appendix B.

[5]Details of the exact ZLB period for each country can be found in Appendix A.

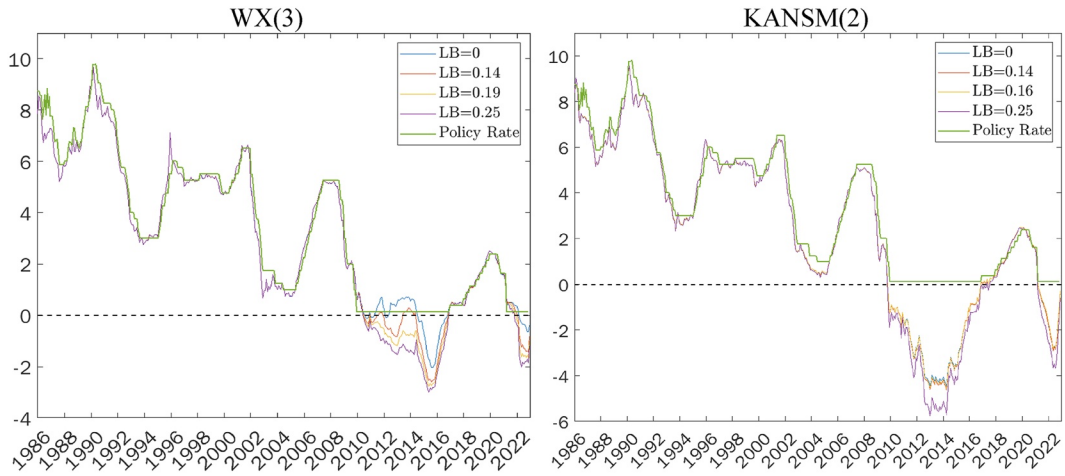

FIGURE 1 WX(3) and KANSM(2) shadow rates for the United States with different lower bound (LB) parameters.

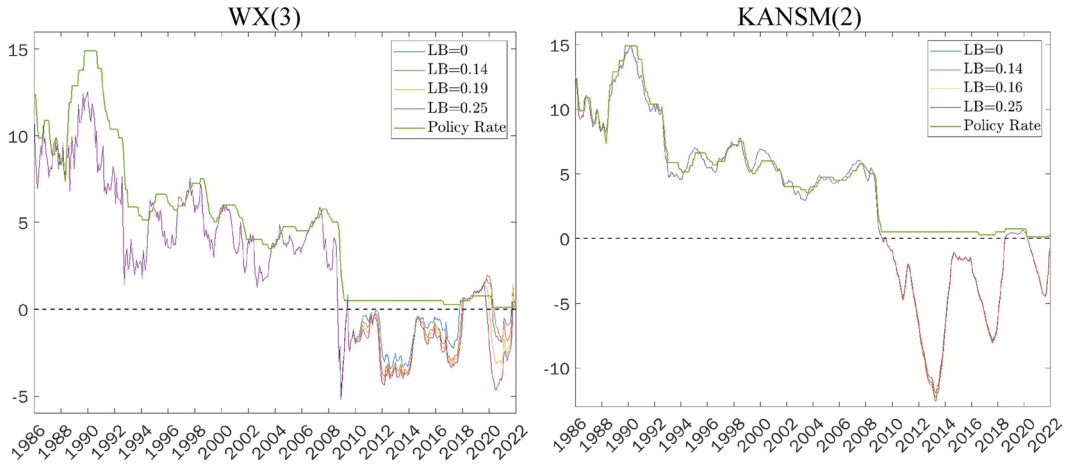

FIGURE 2 WX(3) and KANSM(2) shadow rates for the United Kingdom with different lower bound (LB) parameters.

forecasting analysis we check for robustness by considering the shadow rates computed with the four different LB parameters previously specified.

4.3 | Out-of-sample forecast evaluation

This section evaluates the predictive power of the shadow rates for inflation by means of an out-of-sample forecasting exercise for the regression model given by Equation (1).[6] We report the results of the Diebold-Mariano test comparing the out-of-sample forecasting performance of the model with the shadow rate to that of the benchmark one in Table 1 for countries with a ZLB and in

[6]The results of the in-sample prediction exercises can be found in Appendix D.

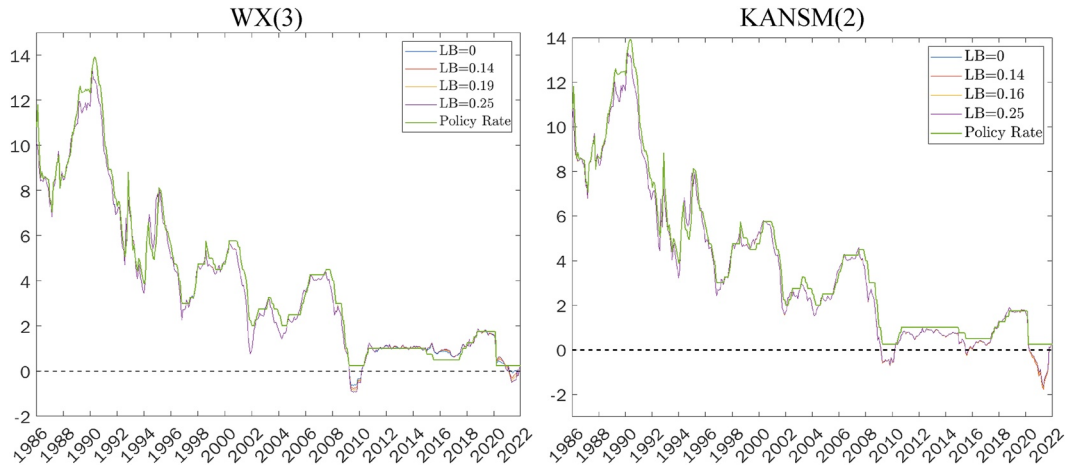

FIGURE 3 WX(3) and KANSM(2) shadow rates for the Canada with different lower bound (LB) parameters.

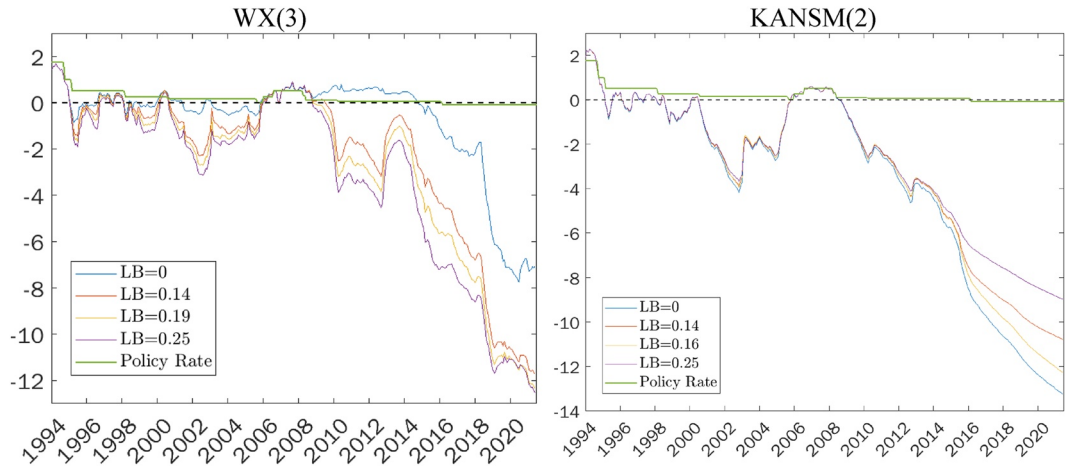

FIGURE 4 WX(3) and KANSM(2) shadow rates for Japan with different lower bound (LB) parameters.

Table 2 for those with negative rates. The results indicate that the models which include the shadow rate outperform the benchmark ones in terms of their out-of-sample forecasting performance in the US and all countries with negative rates. However, in the case of the UK and Canada, the shadow rate does not appear to have much additional predictive power for inflation. It is noteworthy that both these countries adopted an inflation targeting framework in the early 1990s, and thus this finding suggests that unconventional monetary policy has less of an impact on inflation under such an arrangement. On the whole, the forecasting performance results do not appear to be very sensitive to the LB parameter selected to calculate the shadow rates.

Table 3 compares the out-of-sample forecasting performance of the WX(3) shadow rate model with that of the KANSM(2) one for all countries using the Diebold-Mariano test. The results suggest that on the whole the two shadow rate model have a similar forecasting performance, with the WX(3) rate producing more accurate forecasts in the case of Canada and the Euro-Area and the KANSM(2) in the case of the US and Switzerland. These findings stand in contrast to those by Kuusela and Hännikäinen (2017) suggesting a better performance of the three-factor rate in the case of US inflation.

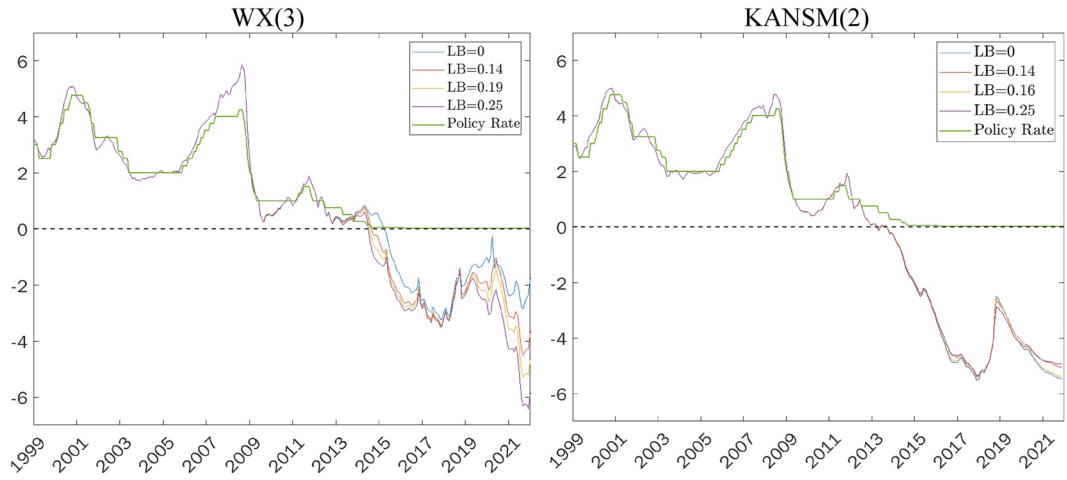

FIGURE 5 WX(3) and KANSM(2) shadow rates for the Euro-Area with different lower bound (LB) parameters.

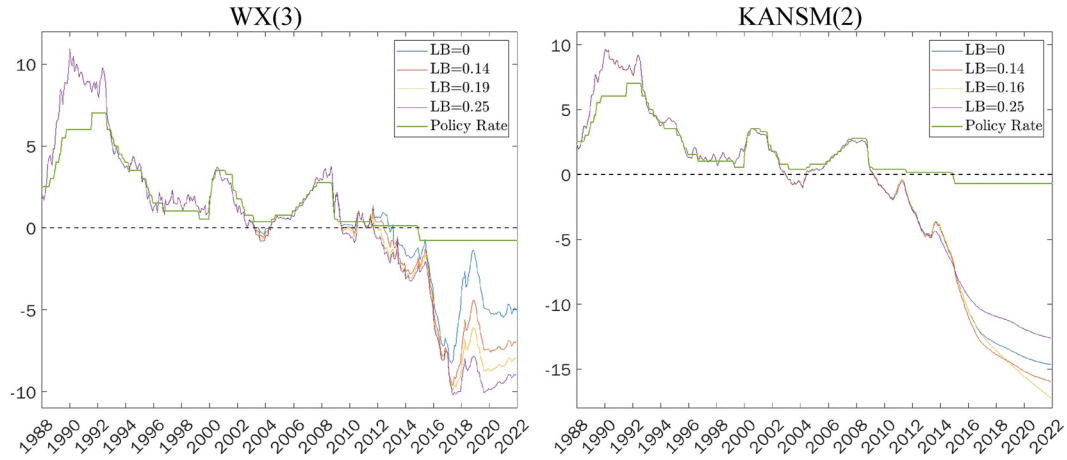

FIGURE 6 WX(3) and KANSM(2) shadow rates for Switzerland with different lower bound (LB) parameters.

4.4 | Density forecast evaluation

The CRPS for the density forecast evaluation is reported in Table 4 for countries with interest rates slightly above or at the ZLB, and in Table 5 for those with negative interest rates. The models with the shadow rate outperform the benchmark ones strongly for most forecasting horizons and for all countries except Canada and the UK, where again the impact of unconventional monetary policy appears to be smaller in the presence of an inflation targeting framework. In other words, the forecast density evaluation suggests that including an appropriate measure of the monetary policy stance such as the shadow rate generally reduces the uncertainty around inflation forecasts at various horizons. Only in inflation targeting countries, which prioritise monetary policy transparency and anchoring inflation expectations, the additional information contained in the shadow rate measure does not produce better forecasts of inflation. This points to the ability of an inflation targeting regime to anchor inflation, even during ZLB periods and in the presence of unconventional policies. Thus the

TABLE 1 Out-of-sample evaluation of the shadow rate model against the benchmark model for countries with a ZLB.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
WX(3)				
United States				
LB = 25	0.2113	0.0000***	0.0000***	0.0000***
LB = 19	0.2113	0.0000***	0.0000***	0.0000***
LB = 14	0.2113	0.0000***	0.0000***	0.0000***
LB = 0	0.7887	0.0000***	0.0000***	0.0000***
United Kingdom				
LB = 25	0.7160	0.8371	0.8937	0.9340
LB = 19	0.6885	0.8173	0.8559	0.8486
LB = 14	0.6935	0.7918	0.6245	0.1621
LB = 0	0.7261	0.7821	0.2200	0.0155**
Canada				
LB = 25	0.8934	0.9629	0.0032***	0.0001***
LB = 19	0.8955	0.9592	0.0050***	0.0002***
LB = 14	0.8961	0.9561	0.0075***	0.0002***
LB = 0	0.8961	0.9509	0.0151**	0.0002***
KANSM(2)				
United States				
LB = 25	0.2113	0.0000***	0.0000***	0.0000***
LB = 16	0.2113	0.0000***	0.0000***	0.0000***
LB = 14	0.4226	0.0000***	0.0000***	0.0000***
LB = 0	0.2113	0.0000***	0.0000***	0.0000***
United Kingdom				
LB = 25	0.7808	0.8689	0.8785	0.2832
LB = 16	0.7755	0.8628	0.8485	0.1571
LB = 14	0.7723	0.8592	0.8325	0.1166
LB = 0	0.7740	0.8613	0.8399	0.1349
Canada				
LB = 25	0.9319	0.9680	0.0046***	0.0022***
LB = 16	0.9317	0.9686	0.0038***	0.0004***
LB = 14	0.9315	0.9691	0.0031***	0.0005***
LB = 0	0.9315	0.9690	0.0031***	0.0000***

Note: Forecasting horizon h. Reported p-values of the Diebold-Mariano test:

H_0: The benchmark model has a smaller or equal loss compared to the shadow rate model.

H_1: The shadow rate model outperforms the benchmark model in terms of predictive accuracy.

*significant at 10%; **significant at 5%; ***significant at 1%.

density forecast results highlight country- and possibly regime-related differences in the usefulness of the shadow rate as a predictor of the inflation rate, which is an important extension to the work of Hännikäinen (2017) analysing only the US case and performing only a point forecast evaluation.

TABLE 2 Out-of-sample evaluation of the shadow rate model against the benchmark model for countries with negative interest rates.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
WX(3)				
Japan				
LB = 25	0.0169**	0.0301**	0.0310**	0.0329**
LB = 19	0.0221**	0.0248**	0.0236**	0.0224**
LB = 14	0.0173**	0.0118**	0.0456**	0.0349**
LB = 0	0.0231**	0.0336**	0.0412**	0.0205**
Euro-area				
LB = 25	0.0190**	0.0198**	0.0202**	0.0206**
LB = 19	0.0191**	0.0196**	0.0197**	0.0199**
LB = 14	0.0193**	0.0195**	0.0195**	0.0196**
LB = 0	0.0147**	0.0151**	0.0153**	0.0154**
Switzerland				
LB = 25	0.0235**	0.0026***	0.0005***	0.0001***
LB = 19	0.0244**	0.0029***	0.0006***	0.0001***
LB = 14	0.0274**	0.0034***	0.0007***	0.0001***
LB = 0	0.0367**	0.0048***	0.0014***	0.0001***
KANSM(2)				
Japan				
LB = 25	0.0179**	0.0180**	0.0179**	0.0183**
LB = 16	0.0237**	0.0233**	0.0237**	0.0237**
LB = 14	0.0277**	0.0281**	0.0251**	0.0237**
LB = 0	0.0204**	0.0203**	0.0204**	0.0204**
Euro-area				
LB = 25	0.0196**	0.0195**	0.0196**	0.0194**
LB = 16	0.0190**	0.0190**	0.0190**	0.0190**
LB = 14	0.0190**	0.0190**	0.0190**	0.0190**
LB = 0	0.0139**	0.0278**	0.0139**	0.0138**
Switzerland				
LB = 25	0.0212**	0.0021***	0.0004***	0.0000***
LB = 16	0.0231**	0.0021***	0.0003***	0.0000***
LB = 14	0.0212**	0.0019***	0.0003***	0.0000***
LB = 0	0.0209**	0.0019***	0.0004***	0.0000***

Note: Forecasting horizon h. Reported p-values of the Diebold-Mariano test:

H_0: The benchmark model has a smaller or equal loss compared to the shadow rate model.

H_1: The shadow rate model outperforms the benchmark model in terms of predictive accuracy.

*significant at 10%; **significant at 5%; ***significant at 1%.

Table 6 presents the results of a direct comparison of the density forecast performance of the WX(3) and the KANSM(2) models for all countries. On the whole, they suggest a similar performance of these two models, which implies that both two-factor and three-factor shadow rates can be useful in

TABLE 3 Out-of-sample evaluation of the WX(3) shadow rate model against the KANSM(2) shadow rate model.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
Countries with a zero lower bound				
United States				
LB = 25	**0.0309**	**0.0691**	**0.0169**	**0.0223**
LB = 19/16	**0.0731**	**0.0511**	**0.0105**	**0.0434**
LB = 14	**0.0181**	**0.0485**	**0.0631**	**0.0585**
LB = 0	**0.0113**	**0.0310**	**0.0593**	**0.0285**
United Kingdom				
LB = 25	0.5868*	0.4091*	**0.0215**	**0.0020**
LB = 19/16	0.7619*	0.6650*	**0.0644**	**0.0019**
LB = 14	0.8717*	0.9064*	**0.0613**	**0.0534**
LB = 0	0.5093*	0.8736*	0.9833*	0.0145*
Canada				
LB = 25	**0.0351**	0.1149	0.0001*	0.0000*
LB = 19/16	**0.0250**	0.0380*	0.0001*	0.0001*
LB = 14	**0.0234**	0.0116*	0.0000*	0.0001*
LB = 0	**0.0237**	0.0052*	0.0000*	0.0001*
Countries with negative interest rates				
Japan				
LB = 25	**0.0407**	0.0836*	0.0239*	**0.0182**
LB = 19/16	**0.0204**	0.0662*	0.0238*	**0.0178**
LB = 14	**0.0203**	0.0666*	0.0233*	**0.0178**
LB = 0	**0.0204**	0.0869*	0.0289*	**0.0184**
Euro-area				
LB = 25	0.0208*	0.0231*	0.0282*	0.0000*
LB = 19/16	0.0211*	0.0184*	0.0173*	0.0000*
LB = 14	0.0212*	0.0145*	0.0817*	0.0000*
LB = 0	0.0866*	0.0105*	0.0809*	0.0000*
Switzerland				
LB = 25	**0.0198**	**0.0018**	**0.0003**	**0.0000**
LB = 19/16	**0.0224**	**0.0018**	**0.0003**	**0.0000**
LB = 14	**0.0194**	**0.0016**	**0.0003**	**0.0000**
LB = 0	**0.0201**	**0.0018**	**0.0003**	**0.0014**

Note: Forecasting horizon h. Reported p-values of the Diebold-Mariano test:

H_0: The benchmark model has a smaller or equal loss compared to the shadow rate model.

H_1: The shadow rate model outperforms the benchmark model in terms of predictive accuracy.

*indicates that the WX(3) model outperforms the KANSM(2) model **bold** indicates that the KANSM(2) model outperforms the WX(3) model.

TABLE 4 Density forecast evaluation of the shadow rate model against the benchmark model for countries with a zero lower bound (ZLB).

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
WX(3)				
United States				
LB = 25	**0.9302**	1.2973	1.0000	**0.4659**
LB = 19	**0.8837**	**0.8192**	**0.9921**	**0.4695**
LB = 14	**0.8605**	1.1081	**0.9816**	**0.5735**
LB = 0	**0.8372**	1.0541	**0.9764**	**0.5609**
United Kingdom				
LB = 25	1.0109	1.0909	1.4167	1.0417
LB = 19	**0.8913**	**0.9798**	1.3155	4.1458
LB = 14	**0.9022**	1.0000	1.3333	4.6458
LB = 0	1.0109	1.0101	1.3274	1.0208
Canada				
LB = 25	3.7445	1.4403	1.1166	**0.6667**
LB = 19	3.5421	1.4403	1.1626	**0.6667**
LB = 14	3.4409	1.4851	**0.9571**	**0.6150**
LB = 0	3.5421	1.4776	**0.9571**	**0.1111**
KANSM(2)				
United States				
LB = 25	**0.8837**	**0.8919**	**0.8819**	**0.7849**
LB = 16	**0.8140**	**0.9189**	**0.8819**	**0.6505**
LB = 14	**0.8372**	**0.9459**	**0.9108**	**0.6416**
LB = 0	**0.7907**	**0.8649**	**0.8740**	**0.7742**
United Kingdom				
LB = 25	**0.9989**	1.1010	1.2976	3.0833
LB = 16	**0.9989**	1.1010	1.2917	**0.8958**
LB = 14	**0.9989**	1.1010	1.4643	**0.9792**
LB = 0	**0.9989**	1.1010	1.4226	1.2500
Canada				
LB = 25	3.1373	1.4851	1.0521	**0.6915**
LB = 16	3.0361	1.3433	1.0644	**0.7238**
LB = 14	3.1373	1.4925	1.0644	**0.0000**
LB = 0	3.1373	1.5000	1.0521	**0.0000**

Note: Forecasting horizon h. CRPS density forecast evaluation. Values in **bold** indicate a better performance compared to the benchmark model.

forecasting models of inflation. Note that our findings are in contrast to those of Hännikäinen (2017), who reports a better forecasting performance of the WX(3) shadow rates. Since Krippner (2015b) advises caution in using three-factor rates, one could argue that our conclusion, based on the density forecasts, is more plausible than that of Hännikäinen (2017), who only considers point forecasts.

TABLE 5 Density forecast evaluation of the shadow rate model against the benchmark model for countries with negative interest rates.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
WX(3)				
Japan				
LB = 25	**0.0000**	**0.9033**	**0.8872**	**0.8962**
LB = 19	**0.0000**	**0.9000**	**0.9010**	**0.9074**
LB = 14	**0.0000**	**0.9016**	**0.9010**	**0.9063**
LB = 0	**0.0000**	**0.9057**	**0.8996**	**0.9049**
Euro-area				
LB = 25	**0.7504**	**0.7590**	**0.7883**	**0.7873**
LB = 19	**0.8291**	**0.8036**	**0.8281**	**0.8454**
LB = 14	**0.8614**	**0.8264**	**0.8482**	**0.8580**
LB = 0	**0.9033**	**0.8587**	**0.8731**	**0.8739**
Switzerland				
LB = 25	**0.7058**	**0.9286**	**0.0000**	**0.0000**
LB = 19	**0.9167**	**0.8571**	**0.0000**	**0.0000**
LB = 14	**0.9167**	**0.8571**	**0.0000**	**0.0000**
LB = 0	**0.8304**	1.3571	**0.0000**	**0.0000**
KANSM(2)				
Japan				
LB = 25	**0.0000**	**0.8975**	**0.8831**	**0.8836**
LB = 16	**0.0000**	**0.8943**	**0.8818**	**0.8818**
LB = 14	**0.0000**	**0.8975**	**0.8831**	**0.8836**
LB = 0	**0.0000**	**0.8943**	**0.8818**	**0.8818**
Euro-area				
LB = 25	1.1279	1.0969	1.1124	1.1292
LB = 16	**0.9990**	**0.9746**	**0.9901**	**0.9967**
LB = 14	1.0137	**0.9864**	1.0008	1.0041
LB = 0	**0.9035**	**0.9736**	**0.9905**	**0.9967**
Switzerland				
LB = 25	**0.6910**	1.2143	**0.0000**	**0.0000**
LB = 16	**0.7340**	1.2143	**0.0000**	**0.0000**
LB = 14	**0.6811**	1.1429	**0.0000**	**0.0000**
LB = 0	**0.6888**	1.2857	**0.0000**	**0.0000**

Note: Forecasting horizon h. CRPS density forecast evaluation. Values in **bold** indicate a better performance compared to the benchmark model.

Finally, we use the Kolmogorov-Smirnov test to compare the forecast errors between the shadow rate forecast model and the benchmark model and report the results in Table 7 for countries with a ZLB and in Table 8 for those with negative interest rates. These confirm that in terms of forecast density the shadow rate model outperforms the benchmark one in all countries.

TABLE 6 Density forecast evaluation of the WX(3) shadow rate model against the KANSM(2) shadow rate model.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
Countries with a zero lower bound				
United States				
LB = 25	**1.0526**	**1.4545**	**1.1339**	0.5936*
LB = 19/16	**1.0857**	**1.2941**	**1.1250**	0.7218*
LB = 14	**1.0278**	**1.1714**	**1.0778**	0.8939*
LB = 0	**1.0588**	**1.2188**	**1.1171**	0.7245*
United Kingdom				
LB = 25	**1.0109**	0.9908*	**1.0917**	0.3378*
LB = 19/16	0.8913*	0.8899*	**1.0184**	**4.6279**
LB = 14	0.9022*	0.9083*	0.9106*	**4.7447**
LB = 0	**1.0109**	0.9174*	0.9331*	0.8167*
Canada				
LB = 25	**1.1935**	0.9698*	**1.0612**	**3.8564**
LB = 19/16	**1.1667**	**1.0722**	**1.0922**	**3.6841**
LB = 14	**1.0968**	0.9950*	0.8991*	**5.5347**
LB = 0	**1.1290**	0.9851*	0.9096*	**2.8000**
Countries with negative interest rates				
Japan				
LB = 25	**1.0000**	**1.0064**	**1.0046**	**1.0143**
LB = 19/16	**1.0000**	**1.0064**	**1.0218**	**1.0290**
LB = 14	**1.0000**	**1.0046**	**1.0202**	**1.0257**
LB = 0	**1.0000**	**1.0128**	**1.0202**	**1.0262**
Euro-Area				
LB = 25	0.6653*	0.6859*	0.7055*	0.7023*
LB = 19/16	0.8300*	0.8246*	0.8363*	0.8481*
LB = 14	0.8498*	0.8378*	0.8475*	0.8545*
LB = 0	0.9998*	0.8820*	0.8814*	0.8767*
Switzerland				
LB = 25	**1.0214**	0.7647*	0.0000*	0.0000*
LB = 19/16	**1.2488**	0.7059*	0.0000*	0.0000*
LB = 14	**1.3460**	0.7500*	0.0000*	0.0000*
LB = 0	**1.2056**	**1.0556**	0.0000*	0.0000*

Note: Forecasting horizon h. CRPS density forecast evaluation. *indicates that the WX(3) model outperforms the KANSM(2) model. **Bold** indicates that the KANSM(2) model outperforms the WX(3) model.

5 | CONCLUSIONS

The aim of this paper was to assess the predictive power for inflation of shadow rates in two sets of countries, some with rates near or at zero (the US, the UK and Canada) and others with rates in the negative region (Japan, the Euro Area and Switzerland) using both point and forecast density

TABLE 7 Kolmogorov-Smirnov test of distribution uniformity for countries with a zero lower bound (ZLB).

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
WX(3)				
United States				
LB = 25	0.9678	0.9708	0.9990	1.0000
LB = 19	0.9690	0.9990	0.9671	1.0000
LB = 14	0.9856	0.9860	0.9862	1.0000
LB = 0	0.9990	0.9968	0.9987	0.9990
United Kingdom				
LB = 25	0.5273	0.5273	0.5273	0.4968
LB = 19	0.5273	0.5273	0.5273	0.4968
LB = 14	0.5273	0.5273	0.5273	0.4968
LB = 0	0.5273	0.5273	0.5273	0.4968
Canada				
LB = 25	0.2804	0.1578	0.0567*	0.1830
LB = 19	0.0355**	0.8501	0.1033	0.1098
LB = 14	0.0495**	0.6546	0.4768	0.3267
LB = 0	0.4135	0.0135**	0.2598	0.2446
KANSM(2)				
United States				
LB = 25	0.9906	0.9907	0.9912	1.0000
LB = 16	0.9940	0.9943	0.9945	1.0000
LB = 14	0.9979	0.9984	0.9986	1.0000
LB = 0	1.0000	1.0000	1.0000	1.0000
United Kingdom				
LB = 25	0.5273	0.5273	0.5273	0.4968
LB = 16	0.5273	0.5273	0.5273	0.4968
LB = 14	0.5273	0.5273	0.5273	0.4968
LB = 0	0.5273	0.5273	0.5273	0.4968
Canada				
LB = 25	0.0146**	0.0217**	0.5950	0.9278
LB = 16	0.2594	0.2711	0.2804	0.1415
LB = 14	0.4135	0.6560	0.0469**	0.9280
LB = 0	0.4315	0.6685	0.5157	0.8501

Note: Forecasting horizon h. Kolmogorov-Smirnov test:

H_0: Uniformity of the probability integral transform.

H_1: Non-uniformity of the probability integral transform.

evaluations. The shadow rates were computed by using two different models, namely the WX(3) and the KANSM(2) ones, and different LB parameters. The forecasting models included macroeconomic factors obtained by using principal component analysis and were estimated by OLS, both with and without a ZLB interaction term, and both point and density forecasts were generated to compare their forecasting performance. Both the much wider country coverage and the density forecast

TABLE 8 Kolmogorov-Smirnov test of distribution uniformity for countries with negative interest rates.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$
WX(3)				
Japan				
LB = 25	1.0000	0.5912	0.9803	0.9780
LB = 19	1.0000	0.5876	0.9804	0.9780
LB = 14	1.0000	0.5865	0.9803	0.9780
LB = 0	1.0000	0.5905	0.9798	0.9776
Euro-area				
LB = 25	0.9707	0.9707	0.9707	0.9707
LB = 19	0.9707	0.9707	0.9707	0.9707
LB = 14	0.9707	0.9707	0.9707	0.9707
LB = 0	0.9707	0.9707	0.9707	0.9707
Switzerland				
LB = 25	0.6405	0.6405	0.6405	0.6405
LB = 19	0.6405	0.6405	0.6405	0.6405
LB = 14	0.6405	0.6405	0.6405	0.6405
LB = 0	0.6405	0.6405	0.6405	0.6405
KANSM(2)				
Japan				
LB = 25	1.0000	0.5800	0.9795	0.9768
LB = 16	1.0000	0.5837	0.9796	0.9769
LB = 14	1.0000	0.5804	0.9796	0.9769
LB = 0	1.0000	0.5832	0.9796	0.9796
Euro-Area				
LB = 25	0.9707	0.9707	0.9707	0.9707
LB = 16	0.9707	0.9707	0.9707	0.9707
LB = 14	0.9707	0.9707	0.9707	0.9707
LB = 0	0.9707	0.9707	0.9707	0.9707
Switzerland				
LB = 25	0.6405	0.6405	0.6405	0.6405
LB = 16	0.6405	0.6405	0.6405	0.6405
LB = 14	0.6405	0.6405	0.6405	0.6405
LB = 0	0.6405	0.6405	0.6405	0.6405

Note: Forecasting horizon h. Kolmogorov-Smirnov test:

H_0: Uniformity of the probability integral transform.

H_1: Non-uniformity of the probability integral transform.

evaluation carried out represent important extensions to the work previously done by Kuusela and Hännikäinen (2017) Hännikäinen (2017) on this topic and produce new valuable evidence.

The results can be summarised as follows. First, the models which include the shadow rate outperform the benchmark ones in terms of their out-of-sample forecasting performance in all countries except those who have adopted an inflation targeting regime, where there is no difference between the

forecasting performance of the two specifications. This suggests that the shadow rate, which captures unconventional monetary policy, contains important information about future inflation except when price stability is the official monetary policy objective. Second, the overall out-of-sample forecasting performance of the two types of shadow rates is rather similar, although the KANSM(2) shadow rate tends to produce more accurate forecasts than the WX(3) one for the US and Switzerland, which is in contrast to the previous findings of Kuusela and Hännikäinen (2017) for the US. Third, the models with an interactive shadow rate term outperform the benchmark ones also in terms of their forecast density for all countries except those with an official inflation targeting regime. Finally, the density forecast analysis implies that the WX(3) and the KANSM(2) shadow rates are equally useful indicators of future inflation and the uncertainty surrounding it.

In brief, our analysis suggests that the information content of shadow rates provides important insights into the future path of inflation and the uncertainty surrounding it, and thus central banks would be well advised to augment their existing inflation forecasting models to capture the effects of the ZLB/unconventional monetary policy environment on the relationship between the shadow rates and future inflation. Further, it appears that in countries which are not constrained by the ZLB, and where interest rates can instead go into negative territory, unconventional monetary policy measures can still be effective. It is also noteworthy that shadow rates are less useful for predicting inflation in countries that have adopted an inflation targeting regime and thereby achieved greater price stability.

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APPENDIX A

Estimation time period for each country:

Country	Sample start date	Sample end date	ELB period
United States	Jan 1985	Dec 2021	Jan 2009—Dec 2015; Mar 2020—Dec 2021
United Kingdom	Jan 1986	Dec 2021	Apr 2009—May 2010; Mar 2020—Dec 2021
Canada	Jan 1986	Dec 2021	Aug 2016—Oct 2017; Mar 2020—Dec 2021
Japan	Jul 1994	Dec 2021	Dec 2008—Dec 2021
Euro-area	Jan 1999	Dec 2021	Nov 2013—Dec 2021
Switzerland	Jan 1988	Dec 2021	Aug 2011—Dec 2021

APPENDIX B

Nelson-Siegel-Svensson model

The Nelson and Siegel (1987) model estimates the instantaneous forward rate for n years ahead with the following continuous function:

$$f_t(n,0) = \beta_0 + \beta_1 \exp\left(\frac{-n}{\tau_1}\right) + \beta_2\left(\frac{n}{\tau_1}\right)\exp\left(\frac{-n}{\tau_1}\right) \tag{B1}$$

The instantaneous forward rates have a starting level of $\beta_0 + \beta_1$ and they asymptotically approximate β_0. Along the entire horizon the forward rates can have a hump for which β_2 determines the magnitude and sign and τ_1 determines the location. While this model tends to fit shorter maturities well, it suffers from issues with capturing the convexity effects at longer maturities and therefore fitting the entire term structure (Gürkaynak et al., 2007).

An extension to model $B1$ was developed by Svensson (1994), who included six parameters to specify the following functional form:

$$f_t(n,0) = \beta_0 + \beta_1 \exp\left(\frac{-n}{\tau_1}\right) + \beta_2\left(\frac{n}{\tau_1}\right)\exp\left(\frac{-n}{\tau_1}\right) + \beta_3\left(\frac{n}{\tau_2}\right)\exp\left(\frac{-n}{\tau_2}\right) \tag{B2}$$

The two additional parameters β_3 and τ_2 allow for a second hump in the forward rate curve, which captures the convexity effect at longer maturities. The corresponding zero-coupon yields one can use to compute the discount function at any horizon are computed as follows:

$$\begin{aligned} y_t(n) = \beta_0 + \beta_1 \frac{1 - exp\left(-\frac{n}{\tau_1}\right)}{\frac{n}{\tau_1}} + \beta_2\left[\frac{1 - exp\left(-\frac{n}{\tau_1}\right)}{\frac{n}{\tau_1}} - exp\left(-\frac{n}{\tau_1}\right)\right] + \\ +\beta_3\left[\frac{1 - exp\left(-\frac{n}{\tau_2}\right)}{\frac{n}{\tau_2}} - exp\left(-\frac{n}{\tau_2}\right)\right] \end{aligned} \tag{B3}$$

The Svensson (1994) model allows to estimate the yield curve and corresponding discount function at all maturities.

APPENDIX C

Data for principal component analysis

United States

Variable	Description	Source	Transformation
Real activity and employment			
RPI	Real Personal income	Federal Reserve bank of St Louis	5
W875RX1	Real Personal income ex transfer receipts	Federal Reserve bank of St Louis	5
DPCERA3M086SBEA	Real Personal consumption expenditures	Federal Reserve bank of St Louis	5
CMRMTSPLx	Real manu. and trade industries sales	Federal Reserve bank of St Louis	5
RETAILx	Retail and food services sales	Federal Reserve bank of St Louis	5
INDPRO	IP index	Federal Reserve bank of St Louis	5
IPFPNSS	IP: Final Products and nonindustrial supplies	Federal Reserve bank of St Louis	5
IPFINAL	IP: Final Products (market group)	Federal Reserve bank of St Louis	5
IPCONGD	IP: Consumer goods	Federal Reserve bank of St Louis	5
IPDCONGD	IP: Durable consumer goods	Federal Reserve bank of St Louis	5
IPNCONGD	IP: Nondurable consumer goods	Federal Reserve bank of St Louis	5
IPBUSEQ	IP: Business equipment	Federal Reserve bank of St Louis	5
IPMAT	IP: Materials	Federal Reserve bank of St Louis	5
IPDMAT	IP: Durable materials	Federal Reserve bank of St Louis	5
IPNMAT	IP: Nondurable materials	Federal Reserve bank of St Louis	5
IPMANSICS	IP: Manufacturing (SIC)	Federal Reserve bank of St Louis	5
IPB51222S	IP: Residential utilities	Federal Reserve bank of St Louis	5

(Continues)

Variable	Description	Source	Transformation
IPFUELS	IP: Fuels	Federal Reserve bank of St Louis	5
CUMFNS	Capacity utilization: Manufacturing	Federal Reserve bank of St Louis	2
HWI	Help-wanted index for United States	Federal Reserve bank of St Louis	2
HWIURATIO	Ratio of help wanted/No. Unemployed	Federal Reserve bank of St Louis	2
CLF16OV	Civilian Labour force	Federal Reserve bank of St Louis	5
CE16OV	Civilian employment	Federal Reserve bank of St Louis	5
UNRATE	Civilian unemployment rate	Federal Reserve bank of St Louis	2
UEMPMEAN	Average Duration of unemployment (Weeks)	Federal Reserve bank of St Louis	2
UEMPLT5	Civilians unemployed - less than 5 Weeks	Federal Reserve bank of St Louis	5
UEMP5TO14	Civilians unemployed for 5–14 Weeks	Federal Reserve bank of St Louis	5
UEMP15OV	Civilians unemployed - 15 Weeks and over	Federal Reserve bank of St Louis	5
UEMP15T26	Civilians unemployed for 15–26 Weeks	Federal Reserve bank of St Louis	5
UEMP27OV	Civilians unemployed for 27 Weeks and over	Federal Reserve bank of St Louis	5
CLAIMSx	Initial claims	Federal Reserve bank of St Louis	5
PAYEMS	All employees: Total nonfarm	Federal Reserve bank of St Louis	5
USGOOD	All employees: Goods-producing industries	Federal Reserve bank of St Louis	5
CES1021000001	All employees: Mining and Logging: Mining	Federal Reserve bank of St Louis	5
USCONS	All employees: Construction	Federal Reserve bank of St Louis	5
MANEMP	All employees: Manufacturing	Federal Reserve bank of St Louis	5
DMANEMP	All employees: Durable goods	Federal Reserve bank of St Louis	5
NDMANEMP	All employees: Nondurable goods	Federal Reserve bank of St Louis	5
SRVPRD	All employees: Service-providing industries	Federal Reserve bank of St Louis	5

Variable	Description	Source	Transformation
USTPU	All employees: Trade, transportation and utilities	Federal Reserve bank of St Louis	5
USWTRADE	All employees: Wholesale trade	Federal Reserve bank of St Louis	5
USTRADE	All employees: Retail trade	Federal Reserve bank of St Louis	5
USFIRE	All employees: Financial activities	Federal Reserve bank of St Louis	5
USGOVT	All employees: Government	Federal Reserve bank of St Louis	5
CES0600000007	Avg weekly hours: Goods-producing	Federal Reserve bank of St Louis	1
AWOTMAN	Avg weekly overtime hours: Manufacturing	Federal Reserve bank of St Louis	2
AWHMAN	Avg weekly hours: Manufacturing	Federal Reserve bank of St Louis	1
HOUST	Housing Starts: Total new Privately owned	Federal Reserve bank of St Louis	4
HOUSTNE	Housing Starts, northeast	Federal Reserve bank of St Louis	4
HOUSTMW	Housing Starts, midwest	Federal Reserve bank of St Louis	4
HOUSTS	Housing Starts, south	Federal Reserve bank of St Louis	4
HOUSTW	Housing Starts, west	Federal Reserve bank of St Louis	4
PERMIT	New private housing Permits (SAAR)	Federal Reserve bank of St Louis	4
PERMITNE	New private housing Premits, northeast (SAAR)	Federal Reserve bank of St Louis	4
PERMITMW	New private housing Permits, midwest (SAAR)	Federal Reserve bank of St Louis	4
PERMITS	New private housing Permits, south (SAAR)	Federal Reserve bank of St Louis	4
PERMITW	New private housing Permits, west (SAAR)	Federal Reserve bank of St Louis	4
AMDMNOx	New orders for durable goods	Federal Reserve bank of St Louis	5
ANDENOx	New orders for nondefense capital goods	Federal Reserve bank of St Louis	5
AMDMUOx	Unfilled orders for durable goods	Federal Reserve bank of St Louis	5

(Continues)

Variable	Description	Source	Transformation
BUSINVx	Total business inventories	Federal Reserve bank of St Louis	5
ISRATIOx	Total business: Inventories to sales ratio	Federal Reserve bank of St Louis	2
Monetary and financial variables			
M1SL	M1 money stock	Federal Reserve bank of St Louis	6
M2SL	M2 money stock	Federal Reserve bank of St Louis	6
M2REAL	Real M2 money stock	Federal Reserve bank of St Louis	5
BOGMBASE	St. Louis adjusted monetary base	Federal Reserve bank of St Louis	6
TOTRESNS	Total Reserves of depository institutions	Federal Reserve bank of St Louis	6
NONBORRES	Reserves of depository institutions, nonborrowed	Federal Reserve bank of St Louis	7
BUSLOANS	Commercial and industrial Loans, all commercial banks	Federal Reserve bank of St Louis	6
REALLN	Real estate Loans at all commercial banks	Federal Reserve bank of St Louis	6
NONREVSL	Total nonrevolving credit owner and securitized outstanding	Federal Reserve bank of St Louis	6
CONSPI	Nonrevolving consumer credit to Personal income	Federal Reserve bank of St Louis	2
S&P 500	S&P's common stock price index: Composite	Federal Reserve bank of St Louis	5
S&P: INDUST	S&P's common stock price index: Industrials	Federal Reserve bank of St Louis	5
S&P DIV YIELD	S&P's composite common stock: Dividend yield	Federal Reserve bank of St Louis	2
S&P PE RATIO	S&P's composite common stock: Price-earnings ratio	Federal Reserve bank of St Louis	5
FEDFUNDS	Effective federal funds rate	Federal Reserve bank of St Louis	2
CP3Mx	3-Month AA financial commercial paper rate	Federal Reserve bank of St Louis	2
TB3MS	3-Month treasury bill	Federal Reserve bank of St Louis	2
TB6MS	6-Month treasury bill	Federal Reserve bank of St Louis	2
GS1	1-Year treasury rate	Federal Reserve bank of St Louis	2

Variable	Description	Source	Transformation
GS5	5-Year treasury rate	Federal Reserve bank of St Louis	2
GS10	10-Year treasury rate	Federal Reserve bank of St Louis	2
AAA	Moody's seasoned Aaa corporate bond yield	Federal Reserve bank of St Louis	2
BAA	Moody's seasoned baa corporate bond yield	Federal Reserve bank of St Louis	2
COMPAPFFx	3-Month commercial paper minus FEDFUNDS	Federal Reserve bank of St Louis	1
TB3SMFFM	3-Month treasury C minus FEDFUNDS	Federal Reserve bank of St Louis	1
TB6SMFFM	6-Month treasury C minus FEDFUNDS	Federal Reserve bank of St Louis	1
T1YFFM	1-Year treasury C minus FEDFUNDS	Federal Reserve bank of St Louis	1
T5YFFM	5-Year treasury C minus FEDFUNDS	Federal Reserve bank of St Louis	1
T10YFFM	10-Year treasury C minus FEDFUNDS	Federal Reserve bank of St Louis	1
AAAFFM	Moody's Aaa corporate bond minus FEDFUNDS	Federal Reserve bank of St Louis	1
BAAFFM	Moody's baa corporate bond minus FEDFUNDS	Federal Reserve bank of St Louis	1
TWEXAFEGSMTHx	Trade Weighted U.S. Dollar index: Major currencies	Federal Reserve bank of St Louis	5
EXSZUSx	Switzerland/U.S. Foreign exchange rate	Federal Reserve bank of St Louis	5
EXJPUSx	Japan/U.S. Foreign exchange rate	Federal Reserve bank of St Louis	5
EXUSUKx	U.S./U.K. Foreige Exchangr Rate	Federal Reserve bank of St Louis	5
EXCAUSx	Canada/U.S. Foreign exchange rate	Federal Reserve bank of St Louis	5
DTCOLNVHFNM	Consumer motor vehicle Loans outstanding	Federal Reserve bank of St Louis	6
DTCTHFNM	Total consumer Loans and Leases outstanding	Federal Reserve bank of St Louis	6
INVEST	Securities in bank credit at all commercial banks	Federal Reserve bank of St Louis	6

(Continues)

Variable	Description	Source	Transformation
Prices and inflation			
WPSFD49207	PPI: Finished goods	Federal Reserve bank of St Louis	6
WPSFD49502	PPI: Finished consumer goods	Federal Reserve bank of St Louis	6
WPSID61	PPI: Intermediate materials	Federal Reserve bank of St Louis	6
WPSID62	PPI: Crude materials	Federal Reserve bank of St Louis	6
OILPRICEx	Crude oil, spliced WTI and cushing	Federal Reserve bank of St Louis	6
PPICMM	PPI: Metals and metal Products	Federal Reserve bank of St Louis	6
CPIAUCSL	CPI: All items	Federal Reserve bank of St Louis	6
CPIAPPSL	CPI: Apparel	Federal Reserve bank of St Louis	6
CPITRNSL	CPI: Transportation	Federal Reserve bank of St Louis	6
CPIMEDSL	CPI: Medical care	Federal Reserve bank of St Louis	6
CUSR0000SAC	CPI: Commodities	Federal Reserve bank of St Louis	6
CUSR0000SAD	CPI: Durables	Federal Reserve bank of St Louis	6
CUSR0000SAS	CPI: Services	Federal Reserve bank of St Louis	6
CPIULFSL	CPI: All items less food	Federal Reserve bank of St Louis	6
CUSR0000SA0L2	CPI: All items less shelter	Federal Reserve bank of St Louis	6
CUSR0000SA0L5	CPI: All items less medical care	Federal Reserve bank of St Louis	6
PCEPI	Personal cons. Expend.: Chain price index	Federal Reserve bank of St Louis	6
DDURRG3M086SBEA	Personal cons. Expend.: Durable goods	Federal Reserve bank of St Louis	6
DNDGRG3M086SBEA	Personal cons. Expend.: Nondurable goods	Federal Reserve bank of St Louis	6
DSERRG3M086SBEA	Personal cons. Expend.: Services	Federal Reserve bank of St Louis	6
CES0600000008	Avg hourly earnings: Goods-producing	Federal Reserve bank of St Louis	6
CES2000000008	Avg hourly earnings: Construction	Federal Reserve bank of St Louis	6

Variable	Description	Source	Transformation
CES3000000008	Avg hourly earnings: Manufacturing	Federal Reserve bank of St Louis	6
UMCSENTx	Consumer sentiment index	Federal Reserve bank of St Louis	2

Note: The transformation codes represent the transformation applied to each variable before including it in the principal component analysis. The transformation codes are: 1, no transformation; 2, first difference; 3, second difference; 4, natural logarithm; 5, first difference of natural logarithm; 6, second difference of natural logarithm. The variable transformation is the same as in Hännikäinen (2017).

United Kingdom

Variable	Description	Source	Transformation
Real activity and employment			
GBRSLRTTO02IXOBSAM	Sales: Retail trade: Total retail trade: Value for the United Kingdom	Federal Reserve bank of St Louis	5
GBRSARTMISMEI	Total Retail trade in the United Kingdom	Federal Reserve bank of St Louis	5
GBRPROINDMISMEI	Production of total industry in the United Kingdom	Federal Reserve bank of St Louis	5
LRHUTTTTGBM156S	Harmonized unemployment rate: Total: All Persons for the United Kingdom	Federal Reserve bank of St Louis	2
LMJVTTUVGBM647S	Total unfilled job vacancies for the United Kingdom	Federal Reserve bank of St Louis	5
LMUNRLTTGBM647S	Registered unemployment level for the United Kingdom	Federal Reserve bank of St Louis	5
XTEXVA01GBM664S	Exports: Value goods for the United Kingdom	Federal Reserve bank of St Louis	5
GBRSLRTTO02IXOBSAM	Sales: Retail trade: Total retail trade: Value for the United Kingdom	Federal Reserve bank of St Louis	5
GBRPROMANMISMEI	Production in total manufacturing for United Kingdom	Federal Reserve bank of St Louis	5
XTNTVA01GBM664S	Net trade: Value goods for the United Kingdom	Federal Reserve bank of St Louis	5
GBRPRINTO01GYSAM	Production: Industry: Total industry: Total industry excluding construction for the United Kingdom	Federal Reserve bank of St Louis	1
GBRPRMITO01IXOBSAM	Production: Mining: Total mining: Total for the United Kingdom	Federal Reserve bank of St Louis	5

(Continues)

Variable	Description	Source	Transformation
GBRPRMNTO01GPSAM	Production: Manufacturing: Total manufacturing: Total manufacturing for the United Kingdom	Federal Reserve bank of St Louis	1
GBRPREND401IXOBSAM	Production: Energy: Production and distribution of electricity, gas, steam and air conditioning: Total for the United Kingdom	Federal Reserve bank of St Louis	5
GBRSLRTTO01GPSAM	Sales: Retail trade: Total retail trade: Volume for the United Kingdom	Federal Reserve bank of St Louis	1
GBRSLRTCR03MLSAM	Sales: Retail trade: Car registration: Passenger cars for the United Kingdom	Federal Reserve bank of St Louis	5
LFHUADTTGBM647S	Harmonized unemployment: Aged 25 and over: All Persons for the United Kingdom	Federal Reserve bank of St Louis	5
LFHU24TTGBM647S	Harmonized unemployment: Aged 15–24: All Persons for the United Kingdom	Federal Reserve bank of St Louis	5
LMUNRRTTGBM156S	Registered unemployment rate for the United Kingdom	Federal Reserve bank of St Louis	2
GBRLORSGPTDSTSAM	Leading indicators OECD: Reference series: Gross domestic Product (GDP): Trend for the United Kingdom	Federal Reserve bank of St Louis	2
GBRLOLITONOSTSAM	Leading indicators OECD: Leading indicators: CLI: Normalised for the United Kingdom	Federal Reserve bank of St Louis	2
GBRLOCOVRNOSTSAM	Leading indicators OECD: Component series: Car registration - sales: Normalised for the United Kingdom	Federal Reserve bank of St Louis	2
GBRLOCOBPNOSTSAM	Leading indicators OECD: Component series: BTS - Production: Normalised for the United Kingdom	Federal Reserve bank of St Louis	2
BSCICP02GBM460S	Business tendency Surveys for manufacturing: Confidence indicators: Composite indicators: European commission and national indicators for the United Kingdom	Federal Reserve bank of St Louis	2

Variable	Description	Source	Transformation
CSESFT02GBM460S	Consumer opinion Surveys: Economic Situation: Future tendency: European commission indicator for the United Kingdom	Federal Reserve bank of St Louis	2
BSCICP03GBM665S	Business tendency Surveys for manufacturing: Confidence indicators: Composite indicators: OECD indicator for the United Kingdom	Federal Reserve bank of St Louis	2
Monetary and financial variables			
MANMM101GBM189S	M1 for the United Kingdom	Federal Reserve bank of St Louis	5
MABMM301GBM189S	M3 for the United Kingdom	Federal Reserve bank of St Louis	5
CCRETT01GBM661N	Real effective exchange rates based on manufacturing consumer price index for the United Kingdom	Federal Reserve bank of St Louis	5
TRESEGGBM052N	Total Reserves excluding gold for United Kingdom	Federal Reserve bank of St Louis	5
RNGBBIS	Real narrow effective exchange rate for United Kingdom	Federal Reserve bank of St Louis	5
NNGBBIS	Narrow effective exchange rate for United Kingdom	Federal Reserve bank of St Louis	5
POLICYRATE	Central bank policy rate	Bank for international settlements	1
0.25	3-Month treasury bill	Bank of England	2
0.5	6-Month treasury bill	Bank of England	2
1	1-Year treasury rate	Bank of England	2
2	2-Year treasury rate	Bank of England	2
3	3-Year treasury rate	Bank of England	2
5	5-Year treasury rate	Bank of England	2
7	7-Year treasury rate	Bank of England	2
10	10-Year treasury rate	Bank of England	2
0.25 LESS POLICY	3-Month treasury bill minus policy rate	Bank of England	1
0.5 LESS POLICY	6-Month treasury bill minus policy rate	Bank of England	1
1 LESS POLICY	1-Year treasury rate minus policy rate	Bank of England	1
2 LESS POLICY	2-Year treasury rate minus policy rate	Bank of England	1

(Continues)

Variable	Description	Source	Transformation
3 LESS POLICY	3-Year treasury rate minus policy rate	Bank of England	1
5 LESS POLICY	5-Year treasury rate minus policy rate	Bank of England	1
7 LESS POLICY	7-Year treasury rate minus policy rate	Bank of England	1
10 LESS POLICY	10-Year treasury rate minus policy rate	Bank of England	1
USD/GBP	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
EUR/GBP	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
CAD/GBP	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
JPY/GBP	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
FTSE100OPEN	FTSE 100 opening price	Bloomberg	5
Prices and inflation			
GBRCPIALLMINMEI	Consumer price index of all items in the United Kingdom	Federal Reserve bank of St Louis	5
CPALTT01GBM659N	Consumer price index: Total all items for the United Kingdom	Federal Reserve bank of St Louis	1
GBRCPICORMINMEI	Consumer price index: All items excluding food and energy for United Kingdom	Federal Reserve bank of St Louis	5
GBRPPDMMINMEI	Domestic Producer prices index: Manufacturing for United Kingdom	Federal Reserve bank of St Louis	5
CPGRLE01GBM659N	Consumer price index: OECD groups: All items non-food and non-energy for the United Kingdom	Federal Reserve bank of St Louis	1
GBRCPIENGMINMEI	Consumer price index: Energy for United Kingdom	Federal Reserve bank of St Louis	5
CPGREN01GBM657N	Consumer price index: OECD groups: Fuel, electricity, and gasoline for the United Kingdom	Federal Reserve bank of St Louis	1
LCEAMN01GBM659S	Hourly earnings: Manufacturing for the United Kingdom	Federal Reserve bank of St Louis	1

Variable	Description	Source	Transformation
PIEAMP02GBM659N	Producer prices index: Economic activities: Domestic manufacturing for the United Kingdom	Federal Reserve bank of St Louis	1
GBRLCEAMN01GPSAM	Labour compensation: Earnings: Manufacturing: Hourly for the United Kingdom	Federal Reserve bank of St Louis	1
GBRPIEAMP02GPM	Producer prices index: Economic activities: Manufacturing: Domestic for the United Kingdom	Federal Reserve bank of St Louis	1
LCEAMN02GBM661S	Weekly earnings: Manufacturing for the United Kingdom	Federal Reserve bank of St Louis	1
GBRCP040100GYM	Consumer price index: Housing, water, electricity, gas and other fuels (COICOP 04): Actual rentals for housing: Total for the United Kingdom	Federal Reserve bank of St Louis	1
GBRCPGRHO01IXOBM	Consumer price index: OECD groups: Housing: Total for the United Kingdom	Federal Reserve bank of St Louis	1
GBRCPGRHO02GYM	Consumer price index: OECD groups: Housing: Housing excluding imputed rentals for housing for the United Kingdom	Federal Reserve bank of St Louis	1
RPIPETROLOIL	RPI: Percentage change over 12 months - Petrol and oil incl fuel oil	Office for national statistics	1
RPIALLGOODS	RPI: Percentage changes over 1 month - all goods	Office for national statistics	1
RPIDWELLING	RPI: Percentage change over 1 month - dwelling insurance and ground rent	Office for national statistics	1
RPIALLSERVICES	RPI: Percentage change over 12 months - all services	Office for national statistics	1

Note: The transformation codes represent the transformation applied to each variable before including it in the principal component analysis. The transformation codes are: 1, no transformation; 2, first difference; 3, second difference; 4, natural logarithm; 5, first difference of natural logarithm; 6, second difference of natural logarithm.

Canada

Variable	Description	Source	Transformation
Real activity and employment			
CANSARTMISMEI	Total Retail trade in Canada	Federal reserve bank of St louis	5
CANSLRTTO01MLSAM	Sales: Retail trade: Total retail trade: Volume for Canada	Federal reserve bank of St louis	5
CANSLMNTO02MLSAM	Sales: Manufacturing: Total manufacturing: Value for Canada	Federal reserve bank of St louis	5
CANPROINDMISMEI	Production of total industry in Canada	Federal reserve bank of t louis	5
LREM64TTCAM156S	Employment rate: Aged 15–64: All persons for Canada	Federal reserve bank of St louis	2
LREM25TTCAM156S	Employment rate: Aged 25–54: All persons for Canada	Federal reserve bank of St louis	2
LRUNTTTTCAM156S	Unemployment rate: Aged 15 and over: All persons for Canada	Federal reserve bank of St louis	2
LRHUTTTTCAM156S	Harmonized unemployment rate: Total: All persons for Canada	Federal reserve bank of St louis	2
LFHUTTTTCAM647S	Total harmonized unemployment: All persons for Canada	Federal reserve bank of St louis	5
LFEAMNTTCAM647S	Employment by economic activity: Manufacturing: All persons for Canada	Federal reserve bank of St louis	5
LFEASETTCAM647S	Employment by economic activity: Services: All persons for Canada	Federal reserve bank of St louis	5
HOHWMN02CAM065N	Weekly hours worked: Manufacturing for Canada	Federal reserve bank of St louis	1
LFWA64TTCAM647S	Working age population: Aged 15–64: All persons for Canada	Federal reserve bank of St louis	5
LFEMTTTTCAM647S	Employed population: Aged 15 and over: All persons for Canada	Federal reserve bank of St louis	5
CANLORSGPNOSTSAM	Leading indicators OECD: Reference series: Gross domestic product (GDP): Normalised for Canada	Federal reserve bank of St louis	5
CANSARTMISMEI	Total retail trade in Canada	Federal reserve bank of St louis	5
CANPROCONMISMEI	Production of total construction in Canada	Federal reserve bank of St louis	5
CANODMNTO02MLSAM	Orders: Manufacturing: Total orders: Value for Canada	Federal reserve bank of St louis	5

Variable	Description	Source	Transformation
LFEAAGTTCAM647S	Employment by economic activity: Agriculture: All persons for Canada	Federal reserve bank of St louis	5
CANPRINTO01MLSAM	Production: Industry: Total industry: Total industry excluding construction for Canada	Federal reserve bank of St louis	5
LFWA25TTCAM647S	Working age population: Aged 25–54: All persons for Canada	Federal reserve bank of St louis	5
CANPROMANMISMEI	Production in total manufacturing for Canada	Federal reserve bank of St louis	5
LFAC24TTCAM647S	Active population: Aged 15–24: All persons for Canada	Federal reserve bank of St louis	5
CANPRCNTO01MLSAM	Production: Construction: Total construction: Total for Canada	Federal reserve bank of St louis	5
CANSTMNIS01STM	Short term statistics: Stocks - manufacturing: Inventories to shipments: Total for Canada	Federal reserve bank of St louis	2
CANSLRTTO02MLSAM	Sales: Retail trade: Total retail trade: Value for Canada	Federal reserve bank of St louis	5
CANLOCOISORSTSAM	Leading indicators OECD: Component series: Inventories to shipments: Original series for Canada	Federal reserve bank of St louis	2
LFESEETTCAM647S	Total employment by professional status: Employees for Canada	Federal reserve bank of St louis	5
LFEACNTTCAM647S	Employment by economic activity: Construction: All persons for Canada	Federal reserve bank of St louis	5
LFEAINTTCAM647S	Employment by economic activity: Industry excluding construction: All persons for Canada	Federal reserve bank of St louis	5
LFEAICTTCAM647S	Employment by economic activity: Industry including construction: All persons for Canada	Federal reserve bank of St louis	5
LFUN25TTCAM647S	Unemployed population: Aged 25–54: Total for Canada	Federal reserve bank of St louis	5
LFEM25TTCAM647S	Employed population: Aged 25–54: All persons for Canada	Federal reserve bank of St louis	5
LFEM64TTCAM647S	Employed population: Aged 15–64: All persons for Canada	Federal reserve bank of St louis	5

(Continues)

Variable	Description	Source	Transformation
LFWATTTTCAM647S	Working age population: Aged 15 and over: All persons for Canada	Federal reserve bank of St louis	5
LRAC25TTCAM156S	Activity rate: Aged 25–54: All persons for Canada	Federal reserve bank of St louis	2
CANPERMITMISMEI	Permits issued for dwelling in Canada	Federal reserve bank of St louis	1
CANWSCNDW01STSAM	Work started: Construction: Dwellings/Residential buildings: Total for Canada	Federal reserve bank of St louis	5
CANODCNPI03MLSAM	Orders: Construction: Permits issued: Dwellings/Residential buildings for Canada	Federal reserve bank of St louis	5
CANLOLITOTRGYSAM	Leading indicators OECD: Leading indicators: Composite leading indicator: Trend restored for Canada	Federal reserve bank of St louis	2
CANLOCOBSNOSTSAM	Leading indicators OECD: Component series: BTS - business situation: Normalised for Canada	Federal reserve bank of St louis	2
CANLOCOMANOSTSAM	Leading indicators OECD: Component series: Monetary aggregates: Normalised for Canada	Federal reserve bank of St louis	2
CANLOLITONOSTSAM	Leading indicators OECD: Leading indicators: CLI: Normalised for Canada	Federal reserve bank of St louis	2
CANLOCOSPNOSTSAM	Leading indicators OECD: Component series: Share prices: Normalised for Canada	Federal reserve bank of St louis	2
CANLOCODWNOSTSAM	Leading indicators OECD: Component series: Construction: Normalised for Canada	Federal reserve bank of St louis	2
CANLOCOSINOSTSAM	Leading indicators OECD: Component series: Interest rate spread: Normalised for Canada	Federal reserve bank of St louis	2
CANLOCOSPORIXOBM	Leading indicators OECD: Component series: Share prices: Original series for Canada	Federal reserve bank of St louis	2

Variable	Description	Source	Transformation
CANLOCOISNOSTSAM	Leading indicators OECD: Component series: Inventories to shipments: Normalised for Canada	Federal reserve bank of St louis	2
CANLORSGPTDSTSAM	Leading indicators OECD: Reference series: Gross domestic product (GDP): Trend for Canada	Federal reserve bank of St louis	2
CANLORSGPRTSTSAM	Leading indicators OECD: Reference series: Gross domestic product (GDP): Ratio to trend for Canada	Federal reserve bank of St louis	2
CANLOCODWORMLSAM	Leading indicators OECD: Component series: Construction: Original series for Canada	Federal reserve bank of St louis	5
CANLOCOBSORSTSAM	Leading indicators OECD: Component series: BTS - business situation: Original series for Canada	Federal reserve bank of St louis	2
CCRETT01CAM661N	Real effective exchange rates based on manufacturing consumer price index for Canada	Federal reserve bank of St louis	5
RNCABIS	Real narrow effective exchange rate for Canada	Federal reserve bank of St louis	5
CANLOCOSIORSTM	Leading indicators OECD: Component series: Interest rate spread: Original series for Canada	Federal reserve bank of St louis	1
Monetary and financial variables			
CANMANMM101IXOBSAM	Monetary aggregates and their components: Narrow money and components: M1 and components: M1 for Canada	Federal reserve bank of St louis	5
MANMM101CAM189S	M1 for Canada	Federal reserve bank of St louis	5
MABMM301CAM189S	M3 for Canada	Federal reserve bank of St louis	5
CANMABMM301GYSAM	Monetary aggregates and their components: Broad money and components: M3: M3 for Canada	Federal reserve bank of St louis	5
TRESEGCAM052N	Total reserves excluding gold for Canada	Federal reserve bank of St louis	5

(Continues)

Variable	Description	Source	Transformation
NNCABIS	Narrow effective exchange rate for Canada	Federal reserve bank of St louis	5
POLICYRATE	Central bank policy rate	Bank for international settlements	1
0.25	3-Month treasury bill	Bank of Canada	2
0.5	6-Month treasury bill	Bank of Canada	2
1	1-Year treasury rate	Bank of Canada	2
2	2-Year treasury rate	Bank of Canada	2
3	3-Year treasury rate	Bank of Canada	2
5	5-Year treasury rate	Bank of Canada	2
7	7-Year treasury rate	Bank of Canada	2
10	10-Year treasury rate	Bank of Canada	2
0.25 LESS POLICY	3-Month treasury bill minus policy rate	Bank of Canada	1
0.5 LESS POLICY	6-Month treasury bill minus policy rate	Bank of Canada	1
1 LESS POLICY	1-Year treasury rate minus policy rate	Bank of Canada	1
2 LESS POLICY	2-Year treasury rate minus policy rate	Bank of Canada	1
3 LESS POLICY	3-Year treasury rate minus policy rate	Bank of Canada	1
5 LESS POLICY	5-Year treasury rate minus policy rate	Bank of Canada	1
7 LESS POLICY	7-Year treasury rate minus policy rate	Bank of Canada	1
10 LESS POLICY	10-Year treasury rate minus policy rate	Bank of Canada	1
USD/CAD	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
EUR/CAD	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
GBP/CAD	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
JPY/CAD	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
SPTSXCOM	S&P TSX composite index	Bloomberg	5

Variable	Description	Source	Transformation
Prices and inflation			
CANCPIENGMINMEI	Consumer price index: Energy for Canada	Federal reserve bank of St louis	5
CANPPDMMINMEI	Domestic producer prices index: Manufacturing for Canada	Federal reserve bank of St louis	5
CANPIEAMP01GPM	Producer prices index: Economic activities: Manufacturing: Total for Canada	Federal reserve bank of St louis	1
PIEAMP01CAM661N	Producer prices index: Economic activities: Total manufacturing for Canada	Federal reserve bank of St louis	2
CPGREN01CAM657N	Consumer price index: OECD groups: Fuel, electricity, and gasoline for Canada	Federal reserve bank of St louis	1
CANCPGRHO01GYM	Consumer price index: OECD groups: Housing: Total for Canada	Federal reserve bank of St louis	1
CANCP040100GYM	Consumer price index: Housing, water, electricity, gas and other fuels (COICOP 04): Actual rentals for housing: Total for Canada	Federal reserve bank of St louis	1
LCEAMN01CAM189S	Hourly earnings: Manufacturing for Canada	Federal reserve bank of St louis	5
CANCPIFODMINMEI	Consumer price index: Food for Canada	Federal reserve bank of St louis	5
CANCPGRGO01GYM	Consumer price index: OECD groups: Goods: Total for Canada	Federal reserve bank of St louis	1
CANPISPPR01GPM	Producer prices index: Stage of processing: Primary products: Total for Canada	Federal reserve bank of St louis	1
CANPIEAFD01GYM	Producer prices index: Economic activities: Manufacture of food products: Total for Canada	Federal reserve bank of St louis	1
LCEAMN06CAM189S	Total earnings: Manufacturing for Canada	Federal reserve bank of St louis	5
CANCPGRSE01GPM	Consumer price index: OECD groups: Services: Total for Canada	Federal reserve bank of St louis	1
CANCPISXHMINMEI	Consumer price index: Services less housing for Canada	Federal reserve bank of St louis	5
PIEAMP02CAM659N	Producer prices index: Economic activities: Domestic manufacturing for Canada	Federal reserve bank of St louis	1

(Continues)

Variable	Description	Source	Transformation
CPGDFD02CAM657N	Consumer price index: Total food excluding restaurants for Canada	Federal reserve bank of St louis	1
PISPPR01CAM661N	Producer prices index: Stage of processing: Total primary products for Canada	Federal reserve bank of St louis	5
PIEAFD01CAM661N	Producer prices index: Economic activities: Total manufacture of food products for Canada	Federal reserve bank of St louis	5

Note: The transformation codes represent the transformation applied to each variable before including it in the principal component analysis. The transformation codes are: 1, no transformation; 2, first difference; 3, second difference; 4, natural logarithm; 5, first difference of natural logarithm; 6, second difference of natural logarithm.

Japan

Variable	Description	Source	Transformation
Real activity and employment			
LFWA64TTJPM647S	Working age population: Aged 15–64: All persons for Japan	Federal reserve bank of St louis	5
LRUN64TTJPM156S	Unemployment rate: Aged 15–64: All persons for Japan	Federal reserve bank of St louis	2
JPNPROINDMISMEI	Production of total industry in Japan	Federal reserve bank of St louis	5
LREM64TTJPM156S	Employment rate: Aged 15–64: All persons for Japan	Federal reserve bank of St louis	2
LRHUTTTTJPM156S	Harmonized unemployment rate: Total: All persons for Japan	Federal reserve bank of St louis	2
LRUNTTTTJPM156S	Unemployment rate: Aged 15 and over: All persons for Japan	Federal reserve bank of St louis	2
JPNSARTMISMEI	Total retail trade in Japan	Federal reserve bank of St louis	5
LREM25TTJPM156S	Employment rate: Aged 25–54: All persons for Japan	Federal reserve bank of St louis	2
LFEMTTTTJPM647S	Employed population: Aged 15 and over: All persons for Japan	Federal reserve bank of St louis	5
LFWA25TTJPM647S	Working age population: Aged 25–54: All persons for Japan	Federal reserve bank of St louis	5
HOHWMN03JPM661S	Monthly hours worked: Manufacturing for Japan	Federal reserve bank of St louis	5
LFESEETTJPM647S	Total employment by professional status: Employees for Japan	Federal reserve bank of St louis	5
JPNPROMANMISMEI	Production in total manufacturing for Japan	Federal reserve bank of St louis	5

Variable	Description	Source	Transformation
JPNSLRTTO02IXOBSAM	Sales: Retail trade: Total retail trade: Value for Japan	Federal reserve bank of St louis	5
LFHUTTTTJPM647S	Total harmonized unemployment: All persons for Japan	Federal reserve bank of St louis	5
HOOVMN03JPM661N	Monthly overtime hours: Manufacturing for Japan	Federal reserve bank of St louis	5
LREMTTTTJPM156S	Employment rate: Aged 15 and over: All persons for Japan	Federal reserve bank of St louis	2
JPNPRINTO01GYSAM	Production: Industry: Total industry: Total industry excluding construction for Japan	Federal reserve bank of st louis	1
LRACTTTTJPM156S	Activity rate: Aged 15 and over: All persons for Japan	Federal reserve bank of St louis	2
JPNLCEAMN01GPSAM	Labour compensation: Earnings: Manufacturing: Hourly for Japan	Federal reserve bank of St louis	1
JPNSTMNIS01IXOBSAM	Short term statistics: Stocks - manufacturing: Inventories to shipments: Total for Japan	Federal reserve bank of St louis	5
JPNPRMNTO01GYSAM	Production: Manufacturing: Total manufacturing: Total manufacturing for Japan	Federal reserve bank of St louis	1
JPNSLRTTO01GYSAM	Sales: Retail trade: Total retail trade: Volume for Japan	Federal reserve bank of St louis	1
LFEACNTTJPM647S	Employment by economic activity: Construction: All persons for Japan	Federal reserve bank of St louis	5
LFEAAGTTJPM647S	Employment by economic activity: Agriculture: All persons for Japan	Federal reserve bank of St louis	5
LFEASETTJPM647S	Employment by economic activity: Services: All persons for Japan	Federal reserve bank of St louis	5
LFEAICTTJPM647S	Employment by economic activity: Industry including construction: All persons for Japan	Federal reserve bank of St louis	5
LFEAINTTJPM647S	Employment by economic activity: Industry excluding construction: All persons for Japan	Federal reserve bank of St louis	5
LFUN64TTJPM647S	Unemployed population: Aged 15–64: All persons for Japan	Federal reserve bank of St louis	5

(Continues)

Variable	Description	Source	Transformation
LFEM74TTJPM647S	Employed population: Aged 15–74: All persons for Japan	Federal reserve bank of St louis	5
LFACTTTTJPM647S	Active population: Aged 15 and over: All persons for Japan	Federal reserve bank of St louis	5
LRAC64TTJPM156S	Activity rate: Aged 15–64: All persons for Japan	Federal reserve bank of St louis	2
JPNWSCNDW01MLSAM	Work started: Construction: Dwellings/Residential buildings: Total for Japan	Federal reserve bank of St louis	5
JPNSTMNTO01IXOBSAM	Short term statistics: Stocks - manufacturing: Total manufacturing: Volume for Japan	Federal reserve bank of St louis	2
Monetary and financial variables			
RBJPBIS	Real broad effective exchange rate for Japan	Federal reserve bank of St louis	5
MANMM101JPM189S	M1 for Japan	Federal reserve bank of St louis	5
MABMM301JPM189S	M3 for Japan	Federal reserve bank of St louis	5
TRESEGJPM052N	Total reserves excluding gold for Japan	Federal reserve bank of St louis	5
JPNMANMM101IXOBSAM	Monetary aggregates and their components: Narrow money and components: M1 and components: M1 for Japan	Federal reserve bank of St louis	5
JPNMABMM301GYSAM	Monetary aggregates and their components: Broad money and components: M3: M3 for Japan	Federal reserve bank of St louis	5
CCRETT01JPM661N	Real effective exchange rates based on manufacturing consumer price index for Japan	Federal reserve bank of St louis	5
POLICYRATE	Central bank policy rate	Bank for international settlements	1
0.25	3-Month treasury bill	Japanese ministry of finance	2
0.5	6-Month treasury bill	Japanese ministry of finance	2
1	1-Year treasury rate	Japanese ministry of finance	2
2	2-Year treasury rate	Japanese ministry of finance	2

Variable	Description	Source	Transformation
3	3-Year treasury rate	Japanese ministry of finance	2
5	5-Year treasury rate	Japanese ministry of finance	2
7	7-Year treasury rate	Japanese ministry of finance	2
10	10-Year treasury rate	Japanese ministry of finance	2
0.25 LESS POLICY	3-Month treasury bill minus policy rate	Japanese ministry of finance	1
0.5 LESS POLICY	6-Month treasury bill minus policy rate	Japanese ministry of finance	1
1 LESS POLICY	1-Year treasury rate minus policy rate	Japanese ministry of finance	1
2 LESS POLICY	2-Year treasury rate minus policy rate	Japanese ministry of finance	1
3 LESS POLICY	3-Year treasury rate minus policy rate	Japanese ministry of finance	1
5 LESS POLICY	5-Year treasury rate minus policy rate	Japanese ministry of finance	1
7 LESS POLICY	7-Year treasury rate minus policy rate	Japanese ministry of finance	1
10 LESS POLICY	10-Year treasury rate minus policy rate	Japanese ministry of finance	1
USD/JPY	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
GBP/JPY	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
CAD/JPY	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
EUR/JPY	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
NIKKEI225	Japan stock index NIKKEI 225	Swiss national bank	5
Prices and inflation			
JPNCPIALLMINMEI	Consumer price index of all items in Japan	Federal reserve bank of St louis	5
CPALTT01JPM659N	Consumer price index: Total all items for Japan	Federal reserve bank of St louis	1

(Continues)

Variable	Description	Source	Transformation
JPNCPICORMINMEI	Consumer price index: All items excluding food and energy for Japan	Federal reserve bank of St louis	5
PITGCG01JPM661N	Producer prices index: Total consumer goods for Japan	Federal reserve bank of St louis	5
LCEAMN01JPM659S	Hourly earnings: Manufacturing for Japan	Federal reserve bank of St louis	1
JPNPPDMMINMEI	Domestic producer prices index: Manufacturing for Japan	Federal reserve bank of St louis	5
CPALCY01JPM661N	Consumer price index: Total, all items for Japan	Federal reserve bank of St louis	5
LCEAPR03JPM661S	Monthly earnings: Private sector for Japan	Federal reserve bank of St louis	5
JPNCPIENGMINMEI	Consumer price index: Energy for Japan	Federal reserve bank of St louis	5
JPNCPGRSE01GYM	Consumer price index: OECD groups: Services: Total for Japan	Federal reserve bank of St louis	1
LCEAMN03JPM661S	Monthly earnings: Manufacturing for Japan	Federal reserve bank of St louis	5
PITGVG01JPM661N	Producer prices index: Investments goods: Total for Japan	Federal reserve bank of St louis	5
PIEAMP02JPM659N	Producer prices index: Economic activities: Domestic manufacturing for Japan	Federal reserve bank of St louis	1
PITGCD01JPM661N	Producer prices index: Total durable consumer goods for Japan	Federal reserve bank of St louis	5
PISPFG01JPM661N	Producer prices index: Stage of processing: Total finished goods for Japan	Federal reserve bank of St louis	5
JPNPIEAMP02GPM	Producer prices index: Economic activities: Manufacturing: Domestic for Japan	Federal reserve bank of St louis	1
JPNPIEAFD02GPM	Producer prices index: Economic activities: Manufacture of food products: Domestic for Japan	Federal reserve bank of St louis	1
JPNPITGND01GPM	Producer prices index: Type of goods: Non durable consumer goods: Total for Japan	Federal reserve bank of St louis	1
JPNPITGCD01GPM	Producer prices index: Type of goods: Durable consumer goods: Total for Japan	Federal reserve bank of St louis	1

Variable	Description	Source	Transformation
JPNPITGVG01GPM	Producer prices index: Type of goods: Investments goods: Total for Japan	Federal reserve bank of St louis	1
PIEAMI02JPM661N	Producer prices index: Economic activities: Domestic mining and Quarrying activities for Japan	Federal reserve bank of St louis	5
PISPIG01JPM661N	Producer prices index: Stage of processing: Total intermediate goods for Japan	Federal reserve bank of St louis	5
CPGREN01JPM659N	Consumer price index: OECD groups: Fuel, electricity, and gasoline for Japan	Federal reserve bank of St louis	1
CPGRLE01JPM657N	Consumer price index: OECD groups: All items non-food and non-energy for Japan	Federal reserve bank of St louis	1
CPGDFD02JPM657N	Consumer price index: Total food excluding restaurants for Japan	Federal reserve bank of St louis	1
PIEAFD02JPM661N	Producer prices index: Economic activities: Domestic manufacture of food products for Japan	Federal reserve bank of St louis	5

Note: The transformation codes represent the transformation applied to each variable before including it in the principal component analysis. The transformation codes are: 1, no transformation; 2, first difference; 3, second difference; 4, natural logarithm; 5, first difference of natural logarithm; 6, second difference of natural logarithm.

Euro-Area

Variable	Description	Source	Transformation
Real activity and employment			
LRHUTTTTEZM156S	Harmonized unemployment rate: Total: All persons for the euro area	Federal reserve bank of St louis	1
EA19SLRTTO02IXOBSAM	Sales: Retail trade: Total retail trade: Value for the euro area	Federal reserve bank of St louis	5
EA19PRINTO01GPSAM	Production: Industry: Total industry: Total industry excluding construction for the euro area	Federal reserve bank of St louis	1
EA19SLMNCD02IXOBSAM	Sales: Manufacturing: Consumer goods durable: Value for the euro area	Federal reserve bank of St louis	5

(Continues)

Variable	Description	Source	Transformation
XTEXVA01EZM664S	Exports: Value goods for the euro area	Federal reserve bank of St louis	5
EA19PRMNVG01IXOBSAM	Production: Manufacturing: Investment goods: Total for the euro area	Federal reserve bank of St louis	5
EA19SLMNVG02IXOBSAM	Sales: Manufacturing: Investment goods: Value for the euro area	Federal reserve bank of St louis	5
EA19PRMNIG01IXOBSAM	Production: Manufacturing: Intermediate goods: Total for the euro area	Federal reserve bank of St louis	5
EA19SLMNIG02IXOBSAM	Sales: Manufacturing: Intermediate goods: Value for the euro area	Federal reserve bank of St louis	5
EA19PRCNTO01GPSAM	Production: Construction: Total construction: Total for the euro area	Federal reserve bank of St louis	1
EA19SLMNTO02IXOBSAM	Sales: Manufacturing: Total manufacturing: Value for the euro area	Federal reserve bank of St louis	5
LFHUTTTTEZM647S	Total harmonized unemployment: All persons for the euro area	Federal reserve bank of St louis	5
EA19SLMNCN02IXOBSAM	Sales: Manufacturing: Consumer goods non durable: Value for the euro area	Federal reserve bank of St louis	5
EA19PRMNTO01GPSAM	Production: Manufacturing: Total manufacturing: Total manufacturing for the euro area	Federal reserve bank of St louis	1
EA19PRMNCG03IXOBSAM	Production: Manufacturing: Consumer goods: Non durable goods for the euro area	Federal reserve bank of St louis	5
EA19PRMNCG02IXOBSAM	Production: Manufacturing: Consumer goods: Durable goods for the euro area	Federal reserve bank of St louis	5
EA19ODCNPI03GPSAM	Orders: Construction: Permits issued: Dwellings/Residential buildings for the euro area	Federal reserve bank of St louis	1
MABMM301EZM189S	M3 for the euro area	Federal reserve bank of St louis	5
RBXMBIS	Real broad effective exchange rate for euro area	Federal reserve bank of St louis	5
MANMM101EZM189S	M1 for the euro area	Federal reserve bank of St louis	5
SPASTT01EZM657N	Total share prices for all shares for the euro area	Federal reserve bank of St louis	1

Variable	Description	Source	Transformation
EA19LORSGPORGYSAM	Leading indicators OECD: Reference series: Gross domestic product (GDP): Original series for the euro area	Federal reserve bank of St louis	2
CSCICP03EZM665S	Consumer opinion surveys: Confidence indicators: Composite indicators: OECD indicator for the euro area	Federal reserve bank of St louis	2
EA19LORSGPNOSTSAM	Leading indicators OECD: Reference series: Gross domestic product (GDP): Normalised for the euro area	Federal reserve bank of St louis	2
NBXMBIS	Broad effective exchange rate for euro area	Federal reserve bank of St louis	5
CCRETT01EZM661N	Real effective exchange rates based on manufacturing consumer price index for the euro area	Federal reserve bank of St louis	5
CSINFT02EZM460S	Consumer opinion surveys: Consumer prices: Future tendency of inflation: European commission and national indicators for the euro area	Federal reserve bank of St louis	2
CCEUSP02EZM655N	Yen to euro spot exchange rate for the euro area	Federal reserve bank of St louis	5
CSESFT02EZM460S	Consumer opinion surveys: Economic situation: Future tendency: European commission indicator for the euro area	Federal reserve bank of St louis	2
EA19LOLITOAASTSAM	Leading indicators OECD: Leading indicators: CLI: Amplitude adjusted for the euro area	Federal reserve bank of St louis	2
CCUSSP01EZM650N	US dollar to national currency spot exchange rate for the euro area	Federal reserve bank of St louis	5
CSCICP02EZM460S	Consumer opinion surveys: Confidence indicators: Composite indicators: European commission and national indicators for the euro area	Federal reserve bank of St louis	2

(Continues)

Variable	Description	Source	Transformation
Monetary and financial variables			
RNXMBIS	Real narrow effective exchange rate for euro area	Federal reserve bank of St louis	5
POLICYRATE	Central bank policy rate	Bank for international settlements	1
0.25	3-Month treasury bill	Eurostat	2
0.5	6-Month treasury bill	Eurostat	2
1	1-Year treasury rate	Eurostat	2
2	2-Year treasury rate	Eurostat	2
3	3-Year treasury rate	Eurostat	2
5	5-Year treasury rate	Eurostat	2
7	7-Year treasury rate	Eurostat	2
10	10-Year treasury rate	Eurostat	2
0.25 LESS POLICY	3-Month treasury bill minus policy rate	Eurostat	1
0.5 LESS POLICY	6-Month treasury bill minus policy rate	Eurostat	1
1 LESS POLICY	1-Year treasury rate minus policy rate	Eurostat	1
2 LESS POLICY	2-Year treasury rate minus policy rate	Eurostat	1
3 LESS POLICY	3-Year treasury rate minus policy rate	Eurostat	1
5 LESS POLICY	5-Year treasury rate minus policy rate	Eurostat	1
7 LESS POLICY	7-Year treasury rate minus policy rate	Eurostat	1
10 LESS POLICY	10-Year treasury rate minus policy rate	Eurostat	1
USD/EUR	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
GBP/EUR	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
CAD/EUR	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
JPY/EUR	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
STOXX600	STOXX 600 opening price	Bloomberg	5

Variable	Description	Source	Transformation
Prices and inflation			
CP0000EZ19M086NEST	Harmonized index of consumer prices: All items for euro area (19 countries)	Federal reserve bank of St louis	5
CPHPTT01EZM659N	Consumer price index: Harmonized prices: Total all items for the euro area	Federal reserve bank of St louis	1
CPHPLA01EZM661N	Consumer price index: Harmonized prices: Total all items less food, energy, tobacco, and alcohol for the euro area	Federal reserve bank of St louis	5
EA19CPALTT01GYM	Consumer price index: All items: Total: Total for the euro area	Federal reserve bank of St louis	1
ENRGY0EZ19M086NEST	Harmonized index of consumer prices: Energy for euro area (19 countries)	Federal reserve bank of St louis	5
EA19CPHPLA01GYM	Consumer price index: Harmonised prices: All items less food, energy, tobacco, alcohol: Total for the euro area	Federal reserve bank of St louis	1
CPHPSE01EZM661N	Consumer price index: Harmonized prices: Total services for the euro area	Federal reserve bank of St louis	5
CP0410EZ18M086NEST	Harmonized index of consumer prices: Actual rentals for housing for euro area (18 countries)	Federal reserve bank of St louis	5
CP0110EZ19M086NEST	Harmonized index of consumer prices: Food for euro area (19 countries)	Federal reserve bank of St louis	5
EA19CPGREN01GPM)	Consumer price index: OECD groups: Energy (fuel, electricity & gasoline): Total for the euro area	Federal reserve bank of St louis	1
CP0711EZ18M086NEST	Harmonized index of consumer prices: Motor cars for euro area (18 countries)	Federal reserve bank of St louis	5
PIEAMP01EZM661N	Producer prices index: Economic activities: Total manufacturing for the euro area	Federal reserve bank of St louis	5
PIEATI01EZM661N	Producer prices index: Economic activities: Total industrial activities for the euro area	Federal reserve bank of St louis	5

(Continues)

Variable	Description	Source	Transformation
PITGCD02EZM661N	Producer prices index: Domestic durable consumer goods for the euro area	Federal reserve bank of St louis	5
CP0931EZ19M086NEST	Harmonized index of consumer prices: Games, toys, and hobbies for euro area (19 countries)	Federal reserve bank of St louis	5
CP0000EZCCM086NEST	Harmonized index of consumer prices: All items for euro area (EA11-2000, EA12-2006, EA13-2007, EA15-2008, EA16-2010, EA17-2013, EA18-2014, EA19)	Federal reserve bank of St louis	5
EA19CPHP0401GYM	Consumer price index: Harmonised prices: Housing, water, electricity, gas and other fuels (COICOP 04): Actual rentals for housing for the euro area	Federal reserve bank of st louis	1
EA19PITGVG01GPM	Producer prices index: Type of goods: Investments goods: Total for the euro area	Federal reserve bank of St louis	1
PIEATI02EZM661N	Producer prices index: Economic activities: Domestic industrial activities for the euro area	Federal reserve bank of St louis	5
PITGCG01EZM661N	Producer prices index: Total consumer goods for the euro area	Federal reserve bank of St louis	5
CP0600EZ19M086NEST	Harmonized index of consumer prices: Health for euro area (19 countries)	Federal reserve bank of St louis	5
EA19CPGRLE01GYM	Consumer price index: OECD groups: All items non-food non-energy: Total for the euro area	Federal reserve bank of St louis	1
PIEAMP02EZM659N	Producer prices index: Economic activities: Domestic manufacturing for the euro area	Federal reserve bank of St louis	1
PIEAEN01EZM661N	Producer prices index: Economic activities: Total energy for the euro area	Federal reserve bank of St louis	5
ELGAS0EZ18M086NEST	Harmonized index of consumer prices: Electricity, gas, solid fuels and heat energy for euro area (18 countries)	Federal reserve bank of St louis	5

Variable	Description	Source	Transformation
EA19CPHPTT01IXEBM	Consumer price index: Harmonised prices: All items: Total for the euro area	Federal reserve bank of St louis	5
CP0700EZCCM086NEST	Harmonized index of consumer prices: Transport for euro area (EA11-2000, EA12-2006, EA13-2007, EA15-2008, EA16-2010, EA17-2013, EA18-2014, EA19)	Federal reserve bank of St louis	5
PITGCG02EZM661N	Producer prices index: Domestic consumer goods for the euro area	Federal reserve bank of St louis	5
EA19CPHP1000GYM	Consumer price index: Harmonised prices: Education (COICOP 10): Total for the euro area	Federal reserve bank of St louis	1
EA19CPHP0600GPM	Consumer price index: Harmonised prices: Health (COICOP 06): Total for the euro area	Federal reserve bank of St louis	1
EA19CPHPGD01IXOBM	Consumer price index: Harmonised prices: Goods: Total for the euro area	Federal reserve bank of St louis	5
EA19CPHPSE01GYM	Consumer price index: Harmonised prices: Services: Total for the euro area	Federal reserve bank of St louis	1

Note: The transformation codes represent the transformation applied to each variable before including it in the principal component analysis. The transformation codes are: 1, no transformation; 2, first difference; 3, second difference; 4, natural logarithm; 5, first difference of natural logarithm; 6, second difference of natural logarithm.

Switzerland

Variable	Description	Source	Transformation
Real activity and employment			
LMUNRRTTCHM156S	Registered unemployment rate for Switzerland	Federal reserve bank of St louis	2
LMUNRLTTCHM647S	Registered unemployment level for Switzerland	Federal reserve bank of St louis	5
CHESARTMISMEI	Total retail trade in Switzerland	Federal reserve bank of St louis	5
LMJVTTUVCHM647S	Total unfilled job vacancies for Switzerland	Federal reserve bank of St louis	5

(Continues)

Variable	Description	Source	Transformation
XTNTVA01CHM664S	Net trade: Value goods for Switzerland	Federal reserve bank of St louis	2
CHELOCOBPNOSTSAM	Leading indicators OECD: Component series: BTS - production: Normalised for Switzerland	Federal reserve bank of St louis	2
CHELORSGPRTSTSAM	Leading indicators OECD: Reference series: Gross domestic product (GDP): Ratio to trend for Switzerland	Federal reserve bank of St louis	2
CHELOCOBDNOSTSAM	Leading indicators OECD: Component series: BTS - demand or orders inflow: Normalised for Switzerland	Federal reserve bank of St louis	2
CHELOCOBPORSTSAM	Leading indicators OECD: Component series: BTS - production: Original series for Switzerland	Federal reserve bank of St louis	2
CHELOCOBDORSTSAM	Leading indicators OECD: Component series: BTS - demand or orders inflow: Original series for Switzerland	Federal reserve bank of St louis	2
BSCICP03CHM665S	Business tendency surveys for manufacturing: Confidence indicators: Composite indicators: OECD indicator for Switzerland	Federal reserve bank of St louis	2
BSOITE02CHM460S	Business tendency surveys for manufacturing: Orders inflow: Tendency: European commission indicator for Switzerland	Federal reserve bank of St louis	2
SPRTE02CHM460S	Business tendency surveys for manufacturing: Production: Tendency: European commission and national indicators for Switzerland	Federal reserve bank of St louis	2
BSCICP02CHM460S	Business tendency surveys for manufacturing: Confidence indicators: Composite indicators: European commission and national indicators for Switzerland	Federal reserve bank of St louis	2

Variable	Description	Source	Transformation
BSOBLV02CHM460S	Business tendency surveys for manufacturing: Order books: Level: European commission and national indicators for Switzerland	Federal reserve bank of St louis	2
STWORKERS	Workers affected by short-time working	Swiss national bank	5
JOBLESSRATE	Jobless rate - total	Swiss national bank	2
JOBLESSRATESA	Jobless rate - seasonally adjusted	Swiss national bank	2
JOBVAC	Notified job vacancies - total	Swiss national bank	5
REGSEEKER	Registered job seekers	Swiss national bank	5
LABOURFO	Labour force	Swiss national bank	4
CHELOCOBFNOSTSAM	Leading indicators OECD: Component series: BTS - finished goods stocks: Normalised for Switzerland	Federal reserve bank of St louis	2
CHELOCOBFORSTSAM	Leading indicators OECD: Component series: BTS - finished goods stocks: Original series for Switzerland	Federal reserve bank of St louis	2
BSFGLV02CHM460S	Business tendency surveys for manufacturing: Finished goods stocks: Level: European commission and national indicators for Switzerland	Federal reserve bank of St louis	2
Monetary and financial variables			
SNBMONTBASE	Swiss monetary base aggregate	Federal reserve bank of St louis	6
RNCHBIS	Real narrow effective exchange rate for Switzerland	Federal reserve bank of St louis	5
NNCHBIS	Narrow effective exchange rate for Switzerland	Federal reserve bank of St louis	5
CCRETT01CHM661N	Real effective exchange rates based on manufacturing consumer price index for Switzerland	Federal reserve bank of St louis	5
POLICYRATE	Central bank policy rate	Bank for international settlements	1
0.25	3-Month treasury bill	Swiss national bank	2
0.5	6-Month treasury bill	Swiss national bank	2
1	1-Year treasury rate	Swiss national bank	2
2	2-Year treasury rate	Swiss national bank	2
3	3-Year treasury rate	Swiss national bank	2
5	5-Year treasury rate	Swiss national bank	2

(Continues)

Variable	Description	Source	Transformation
7	7-Year treasury rate	Swiss national bank	2
10	10-Year treasury rate	Swiss national bank	2
0.25 LESS POLICY	3-Month treasury bill minus policy rate	Swiss national bank	1
0.5 LESS POLICY	6-Month treasury bill minus policy rate	Swiss national bank	1
1 LESS POLICY	1-Year treasury rate minus policy rate	Swiss national bank	1
2 LESS POLICY	2-Year treasury rate minus policy rate	Swiss national bank	1
3 LESS POLICY	3-Year treasury rate minus policy rate	Swiss national bank	1
5 LESS POLICY	5-Year treasury rate minus policy rate	Swiss national bank	1
7 LESS POLICY	7-Year treasury rate minus policy rate	Swiss national bank	1
10 LESS POLICY	10-Year treasury rate minus policy rate	Swiss national bank	1
USD/CHF	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
GBP/CHF	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
CAD/CHF	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
JPY/CHF	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
EUR/CHF	Nominal exchange rate denoted in foreign currency units per unit of domestic currency	Pacific exchange rate service	5
CCYINCIRC	Currency in circulation	Swiss national bank	5
M1AGG	Monetary aggregate M1	Swiss national bank	5
M2AGG	Monetary aggregate M2	Swiss national bank	5
M3AGG	Monetary aggregate M3	Swiss national bank	5
SPITOTAL	SPI swiss performance index - index total (including dividend reinvestment)	Swiss national bank	5
SPIRSHARES	SPI swiss performance index - registered shares	Swiss national bank	5

Variable	Description	Source	Transformation
SPIBSHARES	SPI swiss performance index - bearer shares and participation certificates	Swiss national bank	5
SMI	SMI swiss market index (excluding dividend reinvestment)	Swiss national bank	5
Price and inflation			
CHECPIALLMINMEI	Consumer price index: All items for Switzerland	Federal reserve bank of st louis	5
CHECPICORMINMEI	Consumer price index: All items excluding food and energy for Switzerland	Federal reserve bank of st louis	5
CHECPIENGMINMEI	Consumer price index: Energy for Switzerland	Federal reserve bank of st louis	5
CHECPGRGO01GPM	Consumer price index: OECD groups: Goods: Total for Switzerland	Federal reserve bank of st louis	1
CHECPGRLH01GPM	Consumer price index: OECD groups: Services less housing: Total for Switzerland	Federal reserve bank of st louis	1
CPGREN01CHM657N	Consumer price index: OECD groups: Fuel, electricity, and gasoline for Switzerland	Federal reserve bank of st louis	1
CHECPGRSE01GPM	Consumer price index: OECD groups: Services: Total for Switzerland	Federal reserve bank of st louis	1
PPIINDEX	Index of producer prices: Total - index	Swiss national bank	5
PPICHANGE	Index of producer prices: Total - change compared to the same month 1 year earlier in %	Swiss national bank	1
IMPINDEX	Index of import prices: Total - index	Swiss national bank	5
IMPCHANGE	Index of import prices: Total - change compared to the same month 1 year earlier in %	Swiss national bank	1
SPIINDEX	Total supply price index: Total - index	Swiss national bank	5
SPICHANGE	Total supply price index: Total - change compared to the same month 1 year earlier in %	Swiss national bank	1

Note: The transformation codes represent the transformation applied to each variable before including it in the principal component analysis. The transformation codes are: 1, no transformation; 2, first difference; 3, second difference; 4, natural logarithm; 5, first difference of natural logarithm; 6, second difference of natural logarithm.

APPENDIX D

The in-sample predictions for the model including the shadow rate are reported in Table D1 for countries with interest rates at zero or slightly above it and in Table D2 for those with negative rates. These are the estimation results for the forecasting regression in model (1) and show the relationship between the shadow rates and inflation. The relationship between the shadow rate and inflation is positive for all countries with a ZLB and increases in magnitude with the forecasting horizon. These findings are in line with those by Kuusela and Hännikäinen (2017) and suggest that unconventional monetary policy affects inflation with a time lag. In the countries which experienced negative interest rates at times, the coefficient on the shadow policy rate is negative and thus the forward-looking nature of monetary policy seems to be less relevant in this context. Even when interest rates are above zero, there is the possibility that the policy rate will go into negative territory again in the future, which lowers the inflation expectations of private agents who in their economic decision-making take into account the risk of monetary policy becoming ineffective, which affects actual inflation. It seems that countries with negative interest rates do not face a binding constraint in the sense that unconventional monetary policies, measured by the shadow rate, are effective in influencing the inflation rate even when interest rates are below zero. These results (which are robust to the choice of the LB parameter) are in line with those reported by previous studies suggesting that countries with negative interest rates experience less frequently a binding LB constraint, which means that the inflation rate eventually achieved is closer to the central bank's inflation objective (Schmidt, 2016).

We report the in-sample estimation results for the models including the ZLB interaction term for countries with a ZLB in Table D3 and for those with negative rates in Table D4. It can be seen that the relationship between the shadow rate and future inflation differs between ZLB and non-ZLB periods. The shadow rate coefficient is bigger than in the models without a ZLB interaction term, which indicates a stronger effect on inflation when controlling for the ZLB period. The coefficients on the interaction term are negative and significant for all forecasting horizons. This suggests that the relationship between the shadow rate and future inflation is negative during the ZLB period, that is, when the central bank makes use of unconventional monetary policy measures or when interest rates are negative. The most striking finding is that, in the countries with negative rates, including the ZLB interaction term changes the sign of the shadow rate coefficient from negative to positive during non-ZLB times. This suggests that controlling for periods during which the interest rate was at or below zero provides a more accurate representation of the relationship between the shadow rate and inflation.

TABLE D1 In-sample regression results for countries with a zero lower bound (ZLB).

	$h = 3$	$h = 6$	$h = 9$	$h = 12$	p	m	k
WX (3)							
United States							
LB = 25	0.0096	0.0032*	0.0598***	0.0953***	4	4	3
LB = 19	0.0087	0.0079	0.0644***	0.1010***	4	4	3
LB = 14	0.0297*	0.0201*	0.0693***	0.1068***	4	4	3
LB = 0	0.0653*	0.0715*	0.0758***	0.1134***	4	4	3
United Kingdom							
LB = 25	0.0209***	0.0215***	0.0313***	0.0316***	6	6	4
LB = 19	0.0208***	0.0212***	0.0302***	0.0304***	6	6	4
LB = 14	0.0202***	0.0205***	0.0282***	0.0282***	6	6	4

TABLE D1 (Continued)

	$h = 3$	$h = 6$	$h = 9$	$h = 12$	p	m	k
LB = 0	0.0223***	0.0226***	0.0300***	0.0300***	6	6	4
Canada							
LB = 25	0.0545***	0.0767***	0.0895***	0.0992***	6	6	4
LB = 19	0.0549***	0.0768***	0.0891***	0.0989***	6	6	4
LB = 14	0.0555***	0.0769***	0.0886***	0.0978***	6	6	4
LB = 0	0.0564***	0.0773***	0.0877***	0.0958***	6	6	4
KANSM(2)							
United States							
LB = 25	0.0067*	0.0091*	0.0344***	0.0583***	4	4	3
LB = 16	0.0058	0.0080	0.0394***	0.0658***	4	4	3
LB = 14	0.0058	0.0081	0.0391***	0.0654***	4	4	3
LB = 0	0.0058	0.0081	0.0398***	0.0663***	4	4	3
United Kingdom							
LB = 25	0.0125***	0.0129***	0.0199***	0.0199***	6	6	4
LB = 16	0.0123***	0.0126***	0.0192***	0.0192***	6	6	4
LB = 14	0.0120***	0.0122***	0.0185***	0.0185***	6	6	4
LB = 0	0.0122***	0.0125***	0.0189***	0.0189***	6	6	4
Canada							
LB = 25	0.0529***	0.0760***	0.0935***	0.1100***	6	6	4
LB = 16	0.0527***	0.0759***	0.0938***	0.1100***	6	6	4
LB = 14	0.0525***	0.0758***	0.0939***	0.1100***	6	6	4
LB = 0	0.0525***	0.0758***	0.0939***	0.1100***	6	6	4

Note: Forecasting horizon h. The number of factors k, the lags of factors m and the number of autoregressive lags p are determined using the BIC.

*significant at 10%; **significant at 5%; ***significant at 1%.

TABLE D2 In-sample regression results for countries with negative interest rates.

	$h = 3$	$h = 6$	$h = 9$	$h = 12$	p	m	k
WX (3)							
Japan							
LB = 25	−0.0484*	−0.0035*	−0.0532**	−0.0203**	4	4	3
LB = 19	−0.0421*	−0.0049*	−0.0586**	−0.0215**	4	4	3
LB = 14	−0.0431*	−0.0055*	−0.0655*	−0.0239*	4	4	3
LB = 0	−0.0191	−0.0074	−0.0135*	−0.0278**	4	4	3
Euro-Area							
LB = 25	−0.0216**	−0.0162**	−0.0230***	−0.0621***	4	4	3
LB = 19	−0.0100*	−0.0174**	−0.0246***	−0.0636***	4	4	3
LB = 14	−0.0389*	−0.0180**	−0.0256***	−0.0640***	4	4	3
LB = 0	−0.0211*	−0.0203**	−0.0282***	−0.0646***	4	4	3

(Continues)

TABLE D2 (Continued)

	$h = 3$	$h = 6$	$h = 9$	$h = 12$	p	m	k
Switzerland							
LB = 25	−0.0085*	−0.0078**	−0.0029**	−0.0029**	6	6	4
LB = 19	−0.0082*	−0.0074**	−0.0023**	−0.0011**	6	6	4
LB=14	−0.0068*	−0.0058*	−0.0063**	−0.0028**	6	6	4
LB = 0	−0.0018*	−0.0036*	−0.0056*	−0.0094*	6	6	4
KANSM(2)							
Japan							
LB = 25	−0.0307*	−0.0259**	−0.0911***	−0.0609***	4	4	3
LB = 16	−0.0202*	−0.0158**	−0.0710***	−0.0451***	4	4	3
LB = 14	−0.0235*	−0.0190**	−0.0764***	−0.0494***	4	4	3
LB = 0	−0.0184	−0.0143**	−0.0655***	−0.0414***	4	4	3
Euro-Area							
LB = 25	−0.0099**	−0.0096*	−0.0144***	−0.0399***	4	4	3
LB = 16	−0.0144*	−0.0093*	−0.0140***	−0.0399***	4	4	3
LB = 14	−0.0115*	−0.0096*	−0.0144***	−0.0403***	4	4	3
LB = 0	−0.0152*	−0.0091*	−0.0139***	−0.0397***	4	4	3
Switzerland							
LB = 25	−0.0166***	−0.0166***	−0.0119**	−0.0093	6	6	4
LB = 16	−0.0114***	−0.0116***	−0.0075**	−0.0050	6	6	4
LB = 14	−0.0120***	−0.0120***	−0.0083**	−0.0060	6	6	4
LB = 0	−0.0129***	−0.0129***	−0.0090**	−0.0070	6	6	4

Note: Forecasting horizon h. The number of factors k, the lags of factors m and the number of autoregressive lags p are determined using the BIC.

*significant at 10%; **significant at 5%; ***significant at 1%.

TABLE D3 In-sample regression results for countries with a zero lower bound (ZLB) and a ZLB interaction term.

	$h = 3$		$h = 6$		$h = 9$		$h = 12$				
	φ	ψ	φ	ψ	φ	ψ	φ	ψ	p	m	k
WX (3)											
United States											
LB = 25	0.0431**	−0.0485**	0.0405**	−0.0475**	0.0823***	−0.1893***	0.1273***	−0.2710***	4	4	3
LB = 19	0.0439*	−0.0467*	0.0426*	−0.0435**	0.0816***	−0.1850***	0.1254***	−0.2659***	4	4	3
LB = 14	0.0289*	−0.0491*	0.0274*	−0.0442**	0.0798***	−0.1521***	0.1219***	−0.2217***	4	4	3
LB = 0	0.0245	−0.0657	0.0230*	−0.0707	0.0776***	−0.0704	0.1162***	−0.1075	4	4	3
United Kingdom											
LB = 25	0.0224***	−0.0249*	0.0224***	−0.0254*	0.0297***	−0.0015	0.0291***	−0.0094	6	6	4
LB = 19	0.0224***	−0.0399**	0.0223***	−0.0407**	0.0292***	−0.0176	0.0285***	−0.0274	6	6	4
LB = 14	0.0226***	−0.0799***	0.0225***	−0.0810***	0.0283***	−0.0709**	0.0277***	−0.0799***	6	6	4
LB = 0	0.0233***	−0.0729**	0.0236***	−0.0757**	0.0306***	−0.0943**	0.0302***	−0.0989***	6	6	4
Canada											
LB = 25	0.0580***	−0.3231**	0.0741***	−0.2611*	0.0803***	−0.0868	0.0883***	−0.1182	6	6	4
LB = 19	0.0575***	−0.3425**	0.0747***	−0.2760*	0.0808***	−0.0940	0.0881***	0.1205	6	6	4
LB = 14	0.0573***	−0.3362**	0.0758***	−0.2739	0.0828***	−0.1059	0.0901***	−0.0814	6	6	4
LB = 0	0.0572***	−0.2879	0.0775***	−0.2458	0.0869***	−0.1845	0.0949***	−0.1342	6	6	4
KANSM(2)											
United States											
LB = 25	0.0253*	−0.0307*	0.0299**	−0.0464**	0.0764***	−0.1310***	0.1193***	−0.1891***	4	4	3
LB = 16	0.0405*	−0.0428*	0.0415**	−0.0506**	0.0812***	−0.1552***	0.1255***	−0.2211***	4	4	3
LB = 14	0.0399*	−0.0407*	0.0407*	−0.0471**	0.0807***	−0.1534***	0.1248***	−0.2186***	4	4	3
LB = 0	0.0420	−0.0414	0.0424*	−0.0496*	0.0809***	−0.1562***	0.1251***	−0.2222***	4	4	3

(Continues)

TABLE D3 (Continued)

	$h = 3$		$h = 6$		$h = 9$		$h = 12$				
	φ	ψ	φ	ψ	φ	ψ	φ	ψ	p	m	k
United Kingdom											
LB = 25	0.0133***	−0.0205**	0.0127***	−0.0237**	0.0158***	0.0057	0.0155***	−0.0059	6	6	4
LB = 16	0.0154***	−0.0050	0.0126***	−0.0233**	0.0156***	0.0049	0.0153***	−0.0055	6	6	4
LB = 14	0.0128***	−0.0201**	0.0123***	−0.0227**	0.0152***	0.0046	0.0150***	−0.0051	6	6	4
LB = 0	0.0130***	−0.0203**	0.0125***	−0.0230**	0.0154***	0.0048	0.0152***	−0.0053	6	6	4
Canada											
LB = 25	0.0568***	−0.3736***	0.0677***	−0.3419***	0.0650***	−0.2209**	0.0690***	−0.1143	6	6	4
LB = 16	0.0567***	−0.3590***	0.0676***	−0.3279***	0.0652***	−0.2100**	0.0690***	−0.1130	6	6	4
LB = 14	0.0565***	−0.3411***	0.0677***	−0.3111***	0.0655***	−0.1954**	0.0693***	−0.1096	6	6	4
LB = 0	0.0565***	−0.3418***	0.0677***	−0.3119***	0.0655***	−0.1959**	0.0693***	−0.1103	6	6	4

Note: Forecasting horizon h. The number of factors k, the lags of factors m and the number of autoregressive lags p are determined using the BIC.

*significant at 10%; **significant at 5%; ***significant at 1%.

TABLE D4 In-sample regression results for countries with negative interest rates and a zero lower bound (ZLB) interaction term.

	$h = 3$		$h = 6$		$h = 9$		$h = 12$				
	φ	ψ	φ	ψ	φ	ψ	φ	ψ	p	m	k
WX(3)											
Japan											
LB = 25	0.0049	−0.0043	0.0238**	−0.0554***	0.0346**	−0.0554***	0.0135**	−0.0214***	4	4	3
LB = 19	0.0040	−0.0026	0.0033*	−0.0281***	0.0242*	−0.0360***	0.0152**	−0.0198***	4	4	3
LB = 14	0.0039	−0.0035	0.0141*	−0.0467***	0.0261**	−0.0386***	0.0125*	−0.0352***	4	4	3
LB = 0	0.0097	−0.0079	0.0107*	−0.0103	0.0152**	−0.0387***	0.0188*	−0.0242***	4	4	3
Euro-Area											
LB = 25	0.0322**	−0.0599***	0.0406***	−0.0499**	0.0404***	−0.0467**	0.0371***	−0.0015	4	4	3
LB = 19	0.0439***	−0.0032	0.0430***	−0.0553***	0.0435***	−0.0513**	0.0424***	−0.0061	4	4	3
LB = 14	0.0332***	−0.0671***	0.0456***	−0.0611***	0.0468***	−0.0569**	0.0482***	−0.0133	4	4	3
LB = 0	0.0219**	−0.0686***	0.0514***	−0.0753***	0.0557***	−0.0729***	0.0653***	−0.0377	4	4	3
Switzerland											
LB = 25	0.0276**	−0.0424***	0.0282**	−0.0426***	0.0308***	−0.0414***	0.0307***	−0.0405***	6	6	4
LB = 19	0.0283**	−0.0447***	0.0290**	−0.0449***	0.0317***	−0.0436***	0.0315***	−0.0427***	6	6	4
LB = 14	0.0291***	−0.0464***	0.0298***	−0.0466***	0.0325***	−0.0451***	0.0323***	−0.0440***	6	6	4
LB = 0	0.0302***	−0.0487***	0.0311***	−0.0488***	0.0341***	−0.0467***	0.0339***	−0.0453***	6	6	4
KANSM(2)											
Japan											
LB = 25	0.0037	−0.0065	0.0143**	−0.0399***	0.0309**	−0.0609***	0.0350**	−0.0259***	4	4	3
LB = 16	0.0034	−0.0014	0.0117*	−0.0328***	0.0298*	−0.0407***	0.0328*	−0.0117***	4	4	3
LB = 14	0.0034	−0.0011	0.0182*	−0.0371***	0.0289**	−0.0474***	0.0325*	−0.0164***	4	4	3
LB = 0	0.0030	−0.0012	0.0271*	−0.0323***	0.0269*	−0.0382***	0.0293**	−0.0116***	4	4	3

(Continues)

TABLE D4 (Continued)

	$h = 3$		$h = 6$		$h = 9$		$h = 12$				
	φ	ψ	φ	ψ	φ	ψ	φ	ψ	p	m	k
Euro-Area											
LB = 25	0.0311**	−0.0469***	0.0517***	−0.0620***	0.0549***	−0.0618***	0.0643***	−0.0476**	4	4	3
LB = 16	0.0314**	−0.0475***	0.0508***	−0.0607***	0.0534***	−0.0599***	0.0612***	−0.0437**	4	4	3
LB = 14	0.0313**	−0.0476***	0.0516***	−0.0620***	0.0546***	−0.0616***	0.0634***	−0.0465**	4	4	3
LB = 0	0.0314**	−0.0474***	0.0507***	−0.0605***	0.0532***	−0.0597***	0.0609***	−0.0434***	4	4	3
Switzerland											
LB = 25	0.0150	−0.0323***	0.0150	−0.0323***	0.0195	−0.0328***	0.0197*	−0.0322***	6	6	4
LB = 16	0.0200*	−0.0313***	0.0197*	−0.0312***	0.0240**	−0.0319***	0.0239**	−0.0315***	6	6	4
LB = 14	0.0192*	−0.0311***	0.0193*	−0.0311***	0.0234**	−0.0320***	0.0235**	−0.0315***	6	6	4
LB = 0	0.0187	−0.0317***	0.0189	−0.0318***	0.0230*	−0.0326***	0.0231**	−0.0320***	6	6	4

Note: Forecasting horizon h. The number of factors k, the lags of factors m and the number of autoregressive lags p are determined using the BIC.

*significant at 10%; **significant at 5%; ***significant at 1%.