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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Assessing the effective stance of monetary policy: A factor-based approach*

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Abstract

We present an empirical approach to derive the implicit stance of monetary policy. The indicator can be interpreted as an implied short-term interest rate that is not restricted by the effective lower bound. Factor analysis is used to extract an expectations and term premium component from fitted yield curve data. Based on this, an implied short-term interest rate is constructed, which reflects how much the short-term rate should have fallen to achieve observed drop in long-term yields, assuming it could not have been caused by a fall in the term premium. Following Lombardi and Zhu (2014), we study how the implied rate performs as instrument for monetary policy analysis. Regression analyses suggests that the implied rate provides a good gauge for the identification of non-standard monetary policy shocks, and has responded significantly to financial stress as opposed to the output and inflation gap.

Keywords: interest rates: determination, term structure and effects, monetary policy.
JEL classifications: E43, E52.

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1. Introduction

Before the crisis, the stance of monetary policy was reflected in changes in the central bank's main policy rate. However, against the backdrop of the effective lower bound (ELB) for policy rates and the wide array of unconventional policy measures currently in place, the policy rate no longer accurately reflects the true overall stance of monetary policy. In this paper, we present a single indicator for the overall effective stance of monetary policy of the ECB/Eurosystem[1] that combines both its standard interest-rate policies and non-standard balance sheet policies, assuming the latter are primarily effective by lowering the term premium. In absence of balance sheet policies, the calculated indicator coincides with the three-month money market rate. If the Eurosystem engages in balance sheet policies, we use observed long-term yields to construct an implied 3-month rate that is consistent with an unchanged term premium as of the moment that non-standard measures have been put in place. This reflects the assumptions that balance sheet policies have an impact on the term premium by changing the relative supply of long- versus short-term assets in the economy, with the term premium representing a compensation for aggregate duration risk. As the indicator is inferred from market prices, it can be thought of as an indicator for the effective stance of monetary policy.

This indicator for the overall stance of monetary policy can be regarded as a "shadow rate": it shows how much the 3-month rate must have fallen to explain the observed drop in long-term yields under the assumption that such a drop has not been caused by a fall in the term premium. Note, however that our indicator is not a shadow rate in the sense of Krippner (2013) and Bullard (2013), who use option-theory to calculate a shadow yield curve by subtracting the option-value of holding cash from observed yields. Instead, our indicator is more data-driven, similar in spirit to the approach followed by Lombardi and Zhu (2014). We transpose regularities that applied before the ELB was reached and non-standard measures were introduced to infer the effective stance of monetary policy in a situation when non-standard measures are used. However, whereas these other authors calculate a shadow rate from a broad dataset including information on monetary and financial developments and the central bank balance sheet, we extract an indicator from yield curve data only. In other words, we assume that all information on the monetary stance is priced-in in the term structure of interest rates. In this sense, our indicator is closely related to monetary and financial conditions indices (see section 2).

We show that the implied 3-month interest rate can be a useful additional tool to assess the effective stance of monetary policy, particularly at the ELB when balance sheet policies are in place. Even though our methodology deviates from shadow rate models in the literature, the outcomes are comparable to shadow rates described in other studies that show that central banks have been able to provide substantial additional monetary policy accommodation beyond the ELB. Deviations with other

[1] Decisions on monetary policy are taken by the Governing Council of the ECB, and implemented by the Eurosystem, i.e. the ECB joint with the national central banks in the euro area.

shadow rates can be traced to methodological differences and underlying assumptions, e.g. the exact timing at which the lower bound for policy rates was reached. This highlights that estimation of shadow rates is prone to substantial modelling uncertainty. In our methodology the uncertainty on the level of the indicator of the effective stance of monetary policy is reflected in large confidence bands, which increase when the mean estimate for the indicator moves away from the observed short-term interest rate.

For illustration, we show two applications of our indicator for empirical monetary policy analysis inspired by Lombardi and Zhu (2014). First, acknowledging that the implied short-term rate incorporates both standard interest rate policies and non-standard monetary policy measures, we use it as a dependent variable in a simple Taylor interest rate rule specification. The estimation results suggest that non-standard monetary policy measures – summarized in the implied rate – have responded significantly to financial variables, suggesting that these instruments were geared to alleviating financial market stress. Second, we estimate a simple VAR model for monetary policy analysis where the implied short-term interest rate is included to identify monetary policy shocks. This experiment confirms that the implied rate performs better in identifying a non-standard monetary policy shocks than policy rates that are used traditionally in monetary policy analysis.

The remainder of this paper is structured as follows. In the next section, we discuss briefly the relevant literature on monetary stance indicators and models of the term structure of interest rates. In Section 3, we present our methodology and the main results of our analysis. Next, in Section 4 we discuss the main caveats to our methodology and show how our results compare to those found by authors applying other techniques. In Section 5, we illustrate how our indicator can be applied in policy analysis. Finally, in Section 6 we discuss some issues for follow-up research.

2. Related literature

Our analysis is related to two strands of literature in monetary and financial economics. First, the literature on monetary and financial conditions indices and, second, the emerging literature on shadow rate models for the term structure of interest rates.

We see our contribution related to the strand on monetary condition indices (MCIs) and financial condition indices (FCIs) in that we provide an indicator that summarizes the monetary policy stance based on information inferred from financial variables. The way we construct our indicator is thereby similar to the procedure underlying the definition of MCIs, which are computed as the normalized weighted average of a short-term interest rate as well as an exchange rate (see, e.g., Gerlach and Smets, 2000). Given their standardized values, MCIs provide information on whether markets perceive changes in monetary policy to create tighter or looser financial conditions.[2] FCIs furthermore relate to our indicator in that they can be interpreted as a natural extension of MCIs (Angelopoulou et al., 2014), drawing on a larger set of underlying variables than their monetary counterparts. This extended set of variables allows to extract information from financial markets beyond the one inherent in short-term interest rates and exchange rates. Given that our indicator exploits information embedded in the entire spectrum of the euro area yield curve - that is, short but also longer-term interest rates - it relies on the same kind of data used to construct MCIs and FCIs. Methodologically, our indicator is closely related to the class of MCIs and FCIs that are constructed as weighted averages of the underlying fundamentals. At the same time, however, our indicator is also similar to a class of FCIs which are computed by using factor model techniques (see e.g. Matheson, 2012) such as the largest common component of different macroeconomic and financial variables.[3] This is the case as we calculate our indicator as the weighted average of two extracted factors with weights depending on the individual factor loadings.

Second, our paper relates to the literature on term structure modelling, specifically recent papers utilizing a "shadow rate" approach to deal with nonlinearities in the context of the zero (or effective) lower-bound for nominal interest rates. Shadow rate models build on a methodology first proposed by Black (1995), where the observed short-term rate is equal to an unobservable shadow rate or a specific lower bound (often assumed zero). The unobservable shadow rate is the short-term rate that would prevail in absence of cash and can thus be assumed equal to the option value of substituting to cash. As noted by Lemke and Vladu (2017), popular linear Gaussian affine term structure models fail to take into account that in a low-interest rate environment interest rates have more scope to rise than to decrease. The authors find that an estimated shadow rate term structure performs relatively well in terms of cross-sectional fit of yields over maturities, as well as with respect to forecasting interest rates with shorter maturities over shorter forecast horizons. Moreover, whereas standard Gaussian models find implausibly large forward premia during lower-bound periods, this is mitigated in shadow rate models where forward premia turn out to be close to zero. In the literature on term structure modelling, applications of shadow rate techniques surged as policy rates closed in on the ELB. Standard references include Krippner (2012, 2013), Wu and Xia (2016) and Bauer and Rudebusch (2016). In addition, the recent paper by Lemke and Vladu (2017) mentioned above goes one step further by treating the ELB as a varying parameter. The authors argue, this was particularly relevant in the euro area, where perceptions of the level of the ELB shifted over time when policy rates gradually moved into negative territory.

[2] For a critical discussion of MCIs see Eika et al. (1996).

[3] See Darracq Paries et al. (2014) for a discussion of different ways to compute FCIs as well as a comparison of MCIs and FCIs.

The use of shadow rates as indicators of the effective stance of monetary policy has been suggested by Bullard (2013) who argued that in the context of non-standard monetary policy measures, i.e. forward guidance and balance sheet policies, policy rates do not accurately reflect the actual effective stance of monetary policy. Using a dynamic factor model based on a large collection of financial and monetary data, Lombardi and Zhu (2014) calculate a shadow rate that they use to perform monetary policy analysis. They find that their shadow rate – or indicator[4] - is a reasonable gauge for monetary policy when the ELB is binding. We will repeat their experiments in Section 5 of this paper, to illustrate the potential usefulness of our indicator for the effective stance of monetary policy.

3. Methodology and results

3.1 Methodology

Our analysis starts from a simple two-factor term structure model, where we will use the obtained factors to construct an implied short-term interest rate that serves as a measure for the effective stance of monetary policy. The yield i on a risk-free bond of maturity M at time t is determined by the path of the expected short rates, $E_t\left(i_\tau^{short}\right)$, over the maturity of the bond (the expectations component) and a term premium component, $term\ premium_t^M$, as in Equation (1):

$$i_t^M = \frac{1}{M}\sum_{\tau=t}^{M}\left[E_t\left(i_\tau^{\text{short}}\right)\right] + \text{term premium}_t^M. \quad (1)$$

We follow the definition provided by Kim and Orphanides (2007) that term premia compensate for interest rate or duration risk and represent deviations from the expectations hypothesis. In this sense, the term premium component of bond yields can be considered as being orthogonal to (i.e. uncorrelated with) expectations on future short-term interest rates (the ‘expectations component’). In this paper, we assume that balance sheet policies affect yields through the term premium as a consequence of portfolio-rebalancing effects, for example by reducing duration risk to be absorbed by market participants (see e.g. Vayanos and Vila, 2009). By contrast, forward guidance is assumed to impact yields through the expectations component through a signaling channel. In the literature, there is no consensus on validity of this assumption. For example, Bauer and Rudebusch (2014) argue that not all changes in term premia can be ascribed to balance sheet policies, as signalling information on future policy rates will also contribute to lower term premia. Moreover, they argue conventional models to estimate the term premium are biased and attribute too much variation in forward rates to the term premium. Correcting for this, they argue that balance sheet policies by the Federal Reserve were associated with significant signalling effects on the expected path of policy rates. Against this

[4] That is, their methodology does not belong to the class of shadow rate term structure models discussed above.

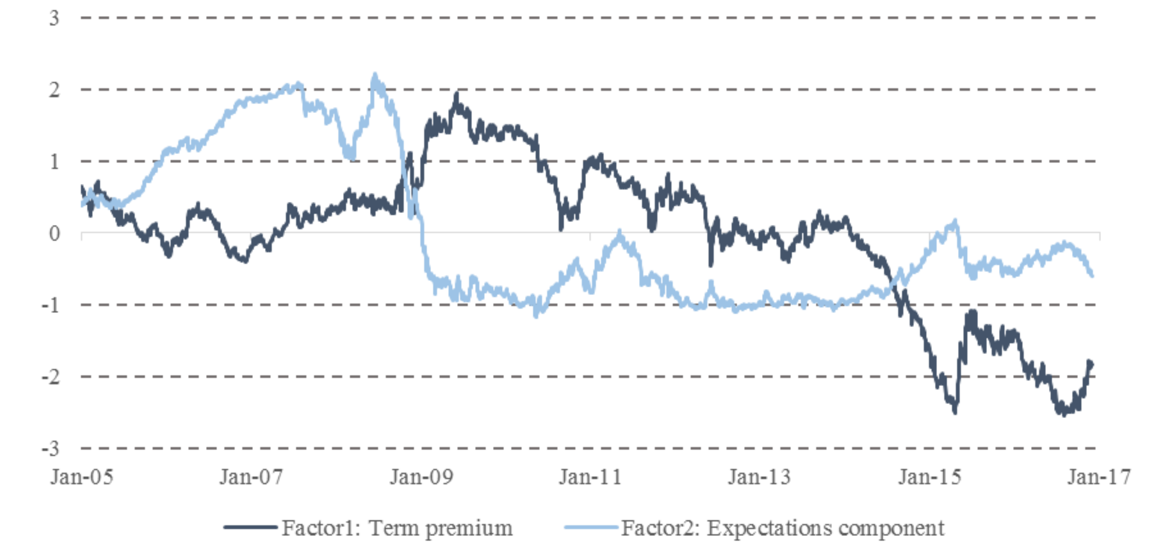
backdrop, we elaborate further on our assumed dichotomy, its plausibility and potential caveats for our results in the discussion in Section 4.

As the expectations component and the term premium are unobservable, one needs a methodology to extract them from the observed data. In this paper we use common factor analysis to extract both components from yield curve data. This is a very simple, a-theoretical and data-driven approach. Key consideration is that factor analysis imposes an orthogonality condition on the extracted factors, in line with the assumption that the expectations component and the term premium should be uncorrelated. A simple two-factor model follows:

$$Z_t^M = \hat{\alpha}_1^M F_{1,t} + \hat{\alpha}_2^M F_{2,t} + \varepsilon_t \tag{2}$$

where Z_t^M refers to the standardized yield for maturity bucket M at time t, $\hat{\alpha}_i^M$ is the loading on factor i for maturity bucket M and $F_{i,t}$ the score of factor i at time t. For the purpose of our exercise we set i=1,2. In addition, ε_t is a mean zero error term that is uncorrelated with the factors.

Figure 1. Extracted common factors
Normalized scores



Note: The first common factor accounts for 60.5% of total variation in the observed data. The second common factor accounts for 39.3% of total variation.

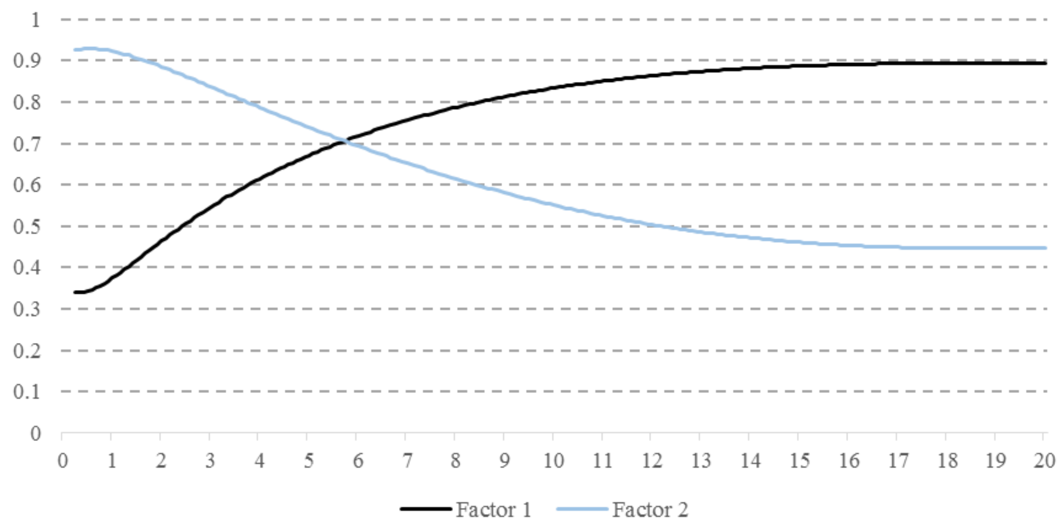
We use daily yield curve data, spanning September 2004 to December 2016, fitted by the ECB's term structure model for which the data is publicly available on the ECB website.[5] This implies that our calculations are essentially a data transformation exercise within the confines of the results fitted by the ECB term structure model. Figure 1 displays the two factors extracted from data on yields over

[5] https://www.ecb.europa.eu/stats/money/yc/html/index.en.html

238 maturity buckets (3-month up till 240-month maturity bucket). The graph shows that shorter-term yields are strongly correlated with Factor 2. Consequently, we interpret this as the latent expectations factor. By contrast, longer-term rates are shown to be more strongly associated with Factor 1. We interpret this as the latent term premium factor.

Note that we use factor analysis purely as a data reduction methodology of the results fitted by the ECB term structure model. That is, we do not estimate a model for the term structure but rather transform the yield curve into two time-varying factors (with factor loadings that are fixed over time) that we subsequently map in an economic context. In the framework of a simple two-factor Nelson-Siegel model, one would interpret the extracted factors as a level and slope factor. In this context, the level factor is often assumed to be associated with the long-term interest rate, whereas the slope factor is associated with the short-term interest rate.[6] Figure 2 confirms that Factor 1 has relatively high loadings on long-term interest rates, whereas Factor 2 loads high on short-term interest rates. The extracted factors can then be assumed to represent the level (in our case this is Factor 1, the term premium) and slope-factor (in our case this is Factor 2, the expectation component) of the model.[7]

Figure 2. Factor loadings over the maturity spectrum



Note: Displays loadings $\hat{\alpha}_i^M$ on factor i over maturities M (on x-axis).

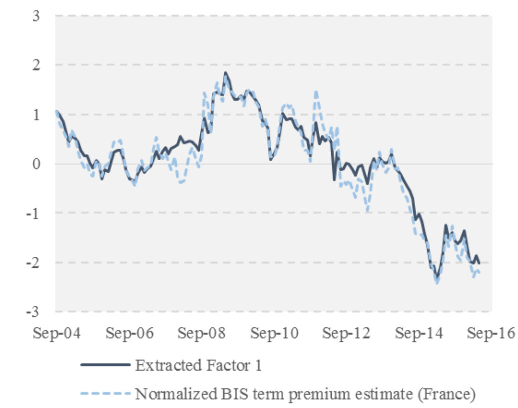
As an alternative to assess our assumptions and economic interpretation, it is useful to explore how our approximation of the term premium compares to actual term premium estimates. Figure 3 confirms that for the euro area our term premium is very much in line with the results from the term structure

[6] See e.g. the discussion by Koopman et al (2010) of the model by Diebold and Li (2006).

[7] Moreover, the analysis assumes that the correlation between observed yields and the latent factors has remained unchanged over the sample period. This assumption may no longer be valid following the anticipation and introduction of the PSPP. This might explain the increase of the second factor towards the end of 2014 shown in Figure 1, which needs not necessarily be associated with higher expectations about the short-term rate.

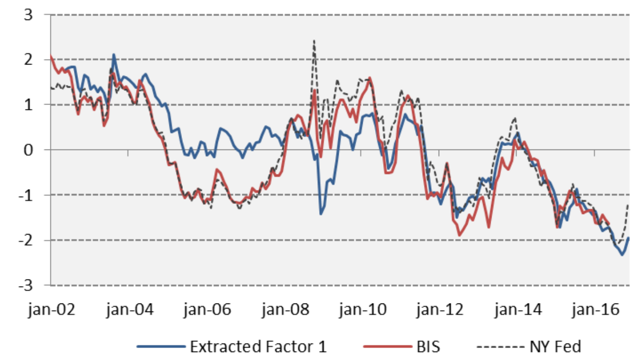
model of the BIS. When we perform a similar back-test with term premium estimates for the US, including also term premium estimates from the Federal Reserve Bank of New York, we get similar results, even though the correlation is somewhat less strong in the years before the global financial crisis (Figure 4).

Figure 3. Euro area term premium estimates
Normalized scores



Note: The estimate for the euro area term premium by the BIS is based on French yields.
Source: BIS (2016) based on Hördahl and Tristani (2014) and authors' own calculations.

Figure 4. US term premium estimates
Normalized scores



Source: BIS (2016) based on Hördahl and Tristani (2014), Federal Reserve Bank of New York and authors' own calculations.

Given the extracted factors, we proceed and construct a short-term rate that assumes balance sheet policies were not in place, and, as a consequence, term premia have remained constant. That is, we aim to assess by how much the 3-month rate[8] should have fallen to achieve the observed drop in long-term yields, assuming it could not have been caused by a fall in the term premium. We do this by fixing the extracted Factor 1 from a specified date onward and recalculate Factor 2 such that it is consistent with actual yield curve data. In mathematical terms, we fix the term premium component $\bar{F}_1$ at t=τ and infer the implied expectations component $\hat{F}_{2,t}^{M}$ for t≥τ from the factor model across M maturity buckets:

$$\hat{F}_{2,t}^{M} = \frac{Z_t^M - \hat{\alpha}_1^M F_{1,t}}{\hat{\alpha}_2^M} \quad \text{if t} < \tau \tag{3a}$$

$$\hat{F}_{2,t}^{M} = \frac{Z_t^M - \hat{\alpha}_1^M \bar{F}_{1,t=\tau}}{\hat{\alpha}_2^M} \quad \text{if t} \geq \tau \tag{3b}$$

8 While the implicit operational target rate of the ECB is the EONIA instead of the 3-month rate, we take the shortest maturity available from the ECB yield curve statistics from a set of 238 maturity buckets. Thus our choice of the policy rate is guided by reasons of practicality. For the purpose of our analysis the difference between taking EONIA and the 3-month rate is irrelevant, as the credit spread only explains a very small proportion of total variation.

Plugging the fixed Factor 1, $\bar{F}_1$, and the implied Factor 2, $\hat{F}_{2,t}^M$,into Equation (2) allows us to construct standardized implied 3-month rates $\hat{Z}_t^M$ for all maturity buckets of the following form:

$$\hat{Z}_t^M = \hat{\alpha}_1^M \bar{F} + \hat{\alpha}_2^M \hat{F}_{2,t}^M. \tag{4}$$

In the next step, we undo the normalization process by multiplying all *M* standardized implied rates by the standard deviation of the actual 3-months interest rate $sd(i^3)$ and adding its mean, $\overline{\iota^3}$, so that we obtain *M* non-standardized implied rates ($\hat{z}_t^M$) of the following form:

$$\hat{z}_t^M = sd(i^3)\hat{Z}_t^M + \overline{\iota^3}. \tag{5}$$

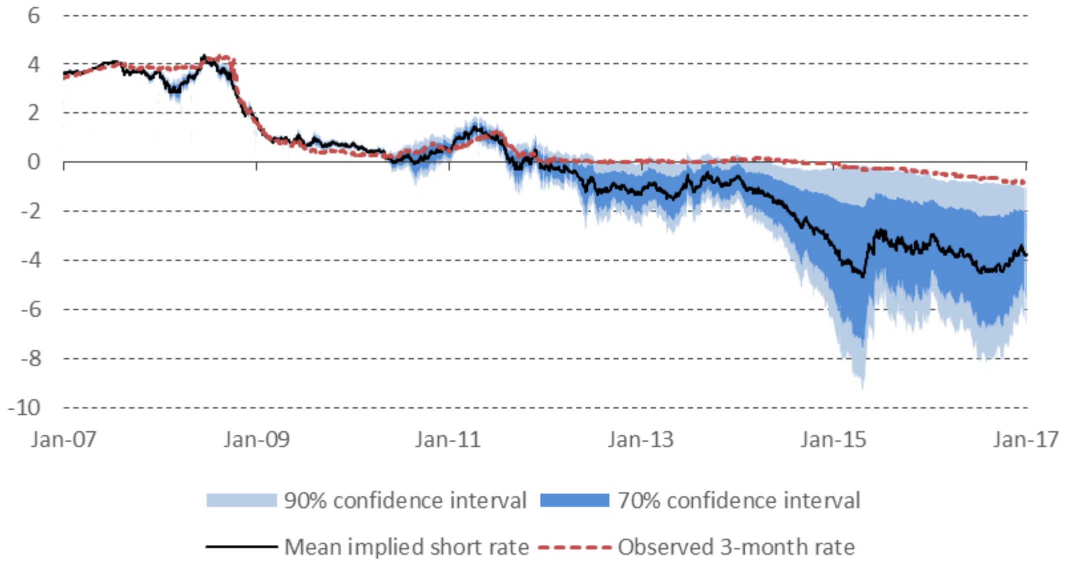
We conduct the steps between Equations (3a) and (5) 1339 times as we fix the first factor $\bar{F}_{1,t=\tau}$ individually for all observations between τ = 24.06.2009, i.e. the day of the first 1 year LTRO, and τ = 10.09.2014, i.e. the day when the MRO rate was set to 0.05%. We take this particular time span as we do not want to pin down the exact date when the Eurosystem started to engage in non-standard monetary policy measures. Given that choice of this date has strong implications for the outcome of our policy indicator, while at the same time there are no clear cut boundaries that allow to identify the exact starting date of the non–standard measures, we prefer to consider a wider time range. This approach also accommodates the observation put forward by Lemke and Vladu (2017) that the perceived ELB for the policy rate may actually vary over time. Different from their approach to model the perceived ELB, we incorporate uncertainty related to this unobservable parameter in our confidence intervals around the constructed indicator for the effective stance of monetary policy. Having 1339 observations with 237 implied policy rates for each point in time, we proceed by computing the mean and standard deviation of the *237* implied policy rates for each observation between June 2009 and September 2014. Based on this information we then calculate in the last step the average over all 1339 observation of both the mean and the standard deviation.

3.2 Results

The resulting mean implied 3-months rate is shown in Figure 5 together with the spectrum of possible rates between the 70% and 90% confidence intervals (i.e. approximately two and three standard deviations around the mean implied rate, respectively). In addition, we also show the actual observed 3-month interest rate (red dotted line). The results show that, based on historical correlations and assuming a constant term premium at the average level over the period June 2009 until September 2014, the yield curve at 30 December 2016 was consistent with a mean estimate for the implied 3-month rate of -3.75%. This number is, however, associated with a significant degree of uncertainty.

For example, 70% of all possible policy rates that we construct lie within the interval ranging from -5.47% to -2.05% (i.e. approximately one standard deviation below and above the mean implied rate). If the level of confidence on the implied short rate would be increased to 90%, the range increases to -6.48% up to -1.04%.

Figure 5. Implied 3-month rate as an indicator for the overall stance of monetary policy



Note: The mean implied 3-month rate is constructed by averaging the calculated implied 3-month rate both over 237 maturity buckets times 1339 date-fixings of the term premium (daily observations from 24 June 2009 until 9 September 2014).

Since the announcement of quantitative easing by the ECB in January 2015, the mean implied short rate has broadly moved within a range of -5% to -3%. Within this interval the variability of the indicator has been quite high, in spite of the fact that the Governing Council of the ECB has only recalibrated its formal monetary policy stance at three intermittent occasions. First, in December 2015 when the date-contingent horizon of the Expanded Asset Purchase Programme (EAPP) was extended from March 2016 until March 2017.[9] Second, in March 2016, when the monthly purchase volumes were increased from EUR 60 billion to EUR 80 billion. Third, most recently, when it was decided in December 2016 to extend the programme horizon to December 2017 and trim the pace of monthly purchases back to EUR 60 billion.

The variability of the mean implied short-term rate reflects its nature as an indicator for the effective stance of monetary policy, i.e. the way the formal stance of monetary policy is translated into market prices. The effective stance of monetary policy is influenced to a large extent by monetary policy, but also by other factors. For example, before the crisis many central banks opted to steer as an operational

[9] In addition, the ECB's APP horizon is state-contingent, as the Governing Council has communicated it will continue the purchases until it sees a sustained adjustment in the path of inflation in line with its aim for price stability.

target the short-term interbank money market close to its main policy rate. This operational target would represent the effective stance of monetary policy that private sector market participants would face as their marginal lending or borrowing rate. In practice, the operational target could deviate slightly from the main policy rate on a day-by-day basis, depending *inter alia* on actual trading activity in the interbank market. When a central bank engages in non-standard measures to push down longer-term interest rates the link between the formal monetary stance and the effective monetary policy stance may become less strong. The central bank has less perfect control over long-term rates relative to short-rates, since long-term rates can be considered to be dependent on factors not related to monetary policy. This includes, for example, investor risk aversion and exogenous shocks to demand and supply for safe-assets (see e.g. Krishnamurthy and Vissing-Jorgensen, 2012). As a consequence, the effective monetary stance becomes more susceptible to factors unrelated to the central bank policy. This is reflected in increased variability in the implied 3-month rate shown in Figure 5. At the same time, the graph confirms that all in all the Eurosystem has been successful in providing significant, additional policy accommodation when policy rates reached the ELB.

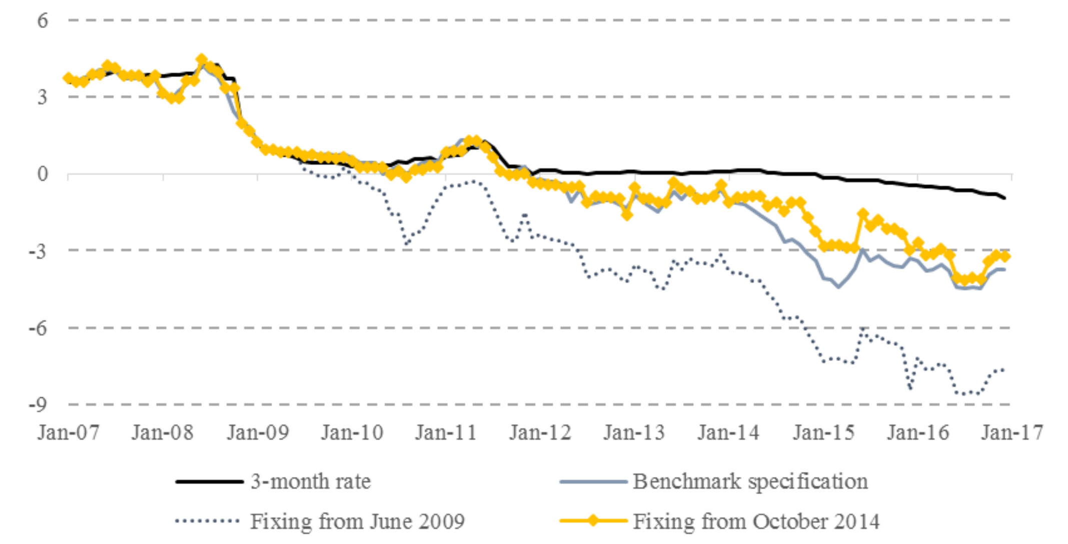
4. Discussion

4.1 Caveats

While the implied short-term rate is a simple indicator that allows for an intuitive assessment of the effective current policy stance, its interpretation is subject to several potential caveats. Importantly, we pick one particular model specification whereas other methodologies may yield different results as highlighted by Christensen and Rudebusch (2013), see also Subsection 4.2. Because of these limitations, one has to keep in mind that our implied short-term rate is only an approximation of the actual policy stance. Moreover, it reflects the view of bond markets on expected monetary policy, which to some extent puts a caveat to the interpretation of the indicator as a measure of the (implied) policy stance as decided by the ECB's decision-making bodies.

In addition, it is important to note that our policy indicator is associated with a significant degree of uncertainty, especially as the implied rate moves away from the actual short-term rate. This can easily be seen by the widening of the range of potential policy rates as shown in Figure 3. In addition, the evolution of the implied rate strongly depends on the date at which we fix the term premium. This is due to the fact that the indicator relies on historical correlations between short and long-term rates which are themselves subject to change – possibly even more so in times of unconventional policies that could be the cause for structural breaks. Figures 6 shows the outcomes of keeping the term premium constant as of June 2009 versus as of October 2014, respectively. To avoid that our policy measure depends on the level of the term premium given at just one particular point in time (as the impact of factors other than QE may also drive the term premium), we construct the indicator as the average implied short–term rate over the period from June 2009 to October 2014.[10]

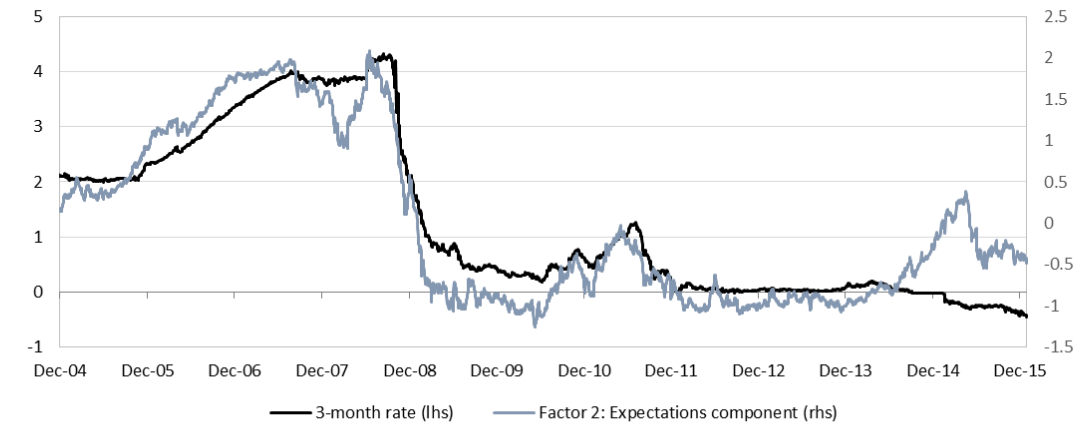
Figure 6. Implied short-rate with varying term premium fixings



Another aspect concerns the underlying definition of the term premium. In this study, we subsume all factors that cause a divergence between short and long-term rates as 'expectation on the short-term rate' and 'term premium'. In theory, however, inflation exceptions are also an important determinant of long-term bond rates. Even though we do not explicitly account for inflation expectations, our extracted term premium is still very much synchronized with estimates inferred from term structure models (see Figures 2 and 3), while the second factor is very much in line with (market expectations of) the short term policy rate (see Figure 7). At the same time, the absence of a factor that accounts explicitly for inflation expectations suggests that our term premium factor might also include an inflation risk premium. Evidence from financial markets suggests that the inflation risk premium has fallen when the economy was experiencing a pronounced period of disinflation up to the fall of 2016 when inflation expectations have started to increase again. This implies that the observed fall in the real term premium that can be attributed to central bank asset purchases might have been less pronounced, implying a potential downward bias in our approximation of the monetary stance. At the same time, balance sheet policies may not only affect yields through the term premium, but also through the expectations component through a signaling channel. This would imply an underestimation of the effects of balance sheet policies.

10 The start date of the window coincides with the first one-year LTRO. The end-date of the window coincides with the MRO-rate reaching its effective lower bound and the ECB signaling it could engage in quantitative easing (see e.g. Draghi, 2014).

Figure 7. Short-term rate and expectations component
Percentage and normalized score.

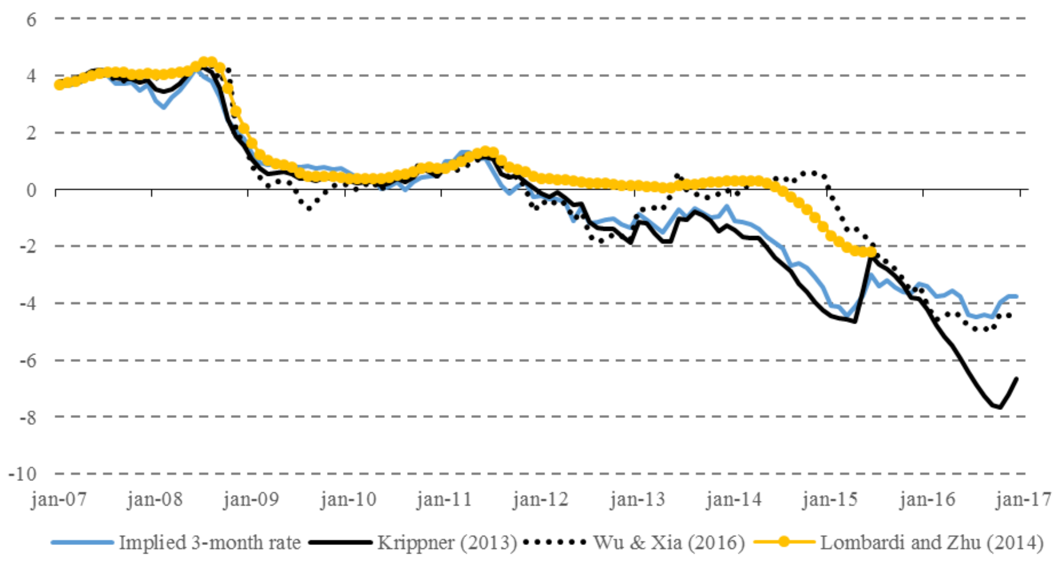


Finally, while being a useful indicator of the effects of unconventional monetary policy, the term premium is also subject to other external factors such as overall uncertainty, or the supply of and demand for the underlying bonds. At the same time, the term premium is not the only channel through which non-standard monetary policy measures affect interest rates. For example, it has been argued that balance sheet policies are mostly effective in enhancing forward guidance by adding credibility to the commitment of keeping interest rates low. This would imply that balance sheet policies are (also) effective through the expectations component of interest rates (signaling channel), as has been argued by Bauer and Rudebusch (2014).

4.2 How does our indicator compare relative to other methodologies?

Against the backdrop of the caveats to our methodology discussed above, it is useful to explore to what extent our results differ from what has been found in other studies. Here, we focus on the results obtained by Krippner (2013; henceforth KR), Wu and Xia (2016; WX) and Lombardi and Zhu (2014, LZ). The results in Figure 8 show that until January 2016 there is a striking similarity between our results and the results found by KR for the euro area, both in terms of the level and the development of the shadow rate. However, after January 2016 the shadow rate calculated by KR drops significantly to a level of -7.65% in October 2016, to increase again by 100 basis points to -6.65% at year-end. By contrast, the similarity between our mean implied 3-month rate and the results found by WX has been very low until early 2016, but has increased thereafter. In fact, the WX shadow rate for the euro area did not deviate significantly from zero until early 2015, but did fall significantly afterwards to levels very similar to our indicator for the effective monetary stance. Finally, the indicator developed by LZ shows yet another pattern. It is broadly stable and above zero until mid-2014, but has fallen since to around -2.20% as the last observations in June 2015.

Figure 8. Euro area mean implied 3-month rate versus shadow rate estimates
Percentage



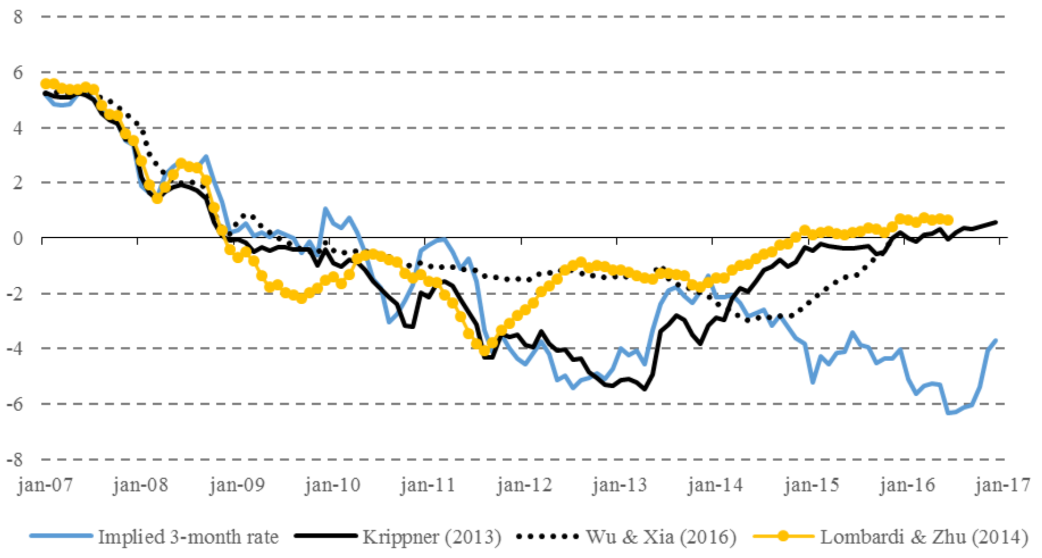
Note: Results from Lombardi and Zhu (2014) only available until June 2015.
Source: Krippner (2013), Wu and Xia (2016), and authors' own calculations.

Next, we also apply our methodology to US yield curve data to obtain a US implied 3-month rate and compare our results once again with the methodologies of the three studies mentioned above.[11] Interestingly, Figure 9 shows that the correlation of our mean implied 3-month rate for the US with the shadow rate found by KR is relatively high in the first part of our sample, as was the case with the results for the euro area. The correlation breaks down by end-2013 when the KR shadow rate gradually reverts back to zero in early 2016 while our indicator falls to a minimum level of approximately -6.30% in mid-2016, only to increase afterwards while remaining significantly below zero. This divergence in results can be traced back to differences in methodology between KR and our approach that are also likely to explain the differences that we have observed for the euro area results shown in Figure 8. As noted in Section 2, shadow rate term structure models originate from Black's (1995) proposal that in the context of the ELB for interest rates, the shadow rate can be considered the option-value of holding cash as the shadow rate is the interest rate that would prevail in absence of a possibility to substitute into cash. As a consequence, the option-value of cash increases when actual yields are closer to the zero lower bound (the strike price of the option) and when yields are expected to remain close to zero for a longer period of time. By contrast, the option-value decreases when the expected date of policy rate lift-off moves closer, which has occurred from end-2013 onwards after the Federal

[11] Another recent paper on the shadow rate for the US is Akkaya at el. (2015). We do not include their shadow rate in our analysis because the data and the paper are not publically available.

Reserve announced it would taper the pace of its asset purchases. Thus, the shadow rate constructed by KR is to a large extent determined by expectations on the future policy rate. By contrast, our indicator is driven by developments in the term premium, which has fallen in the US from mid-2014 onwards as shown in Figure 4, contributing to a fall in the implied 3-month rate. In other words, whereas the approach by KR suggests that non-standard monetary policy accommodation is removed as soon as the policy rate is raised from its ELB, our approach reflects the fact that non-standard measures have a much more enduring impact on the degree of monetary policy accommodation through its effect of maintaining a persistently lower term premium.

Figure 9. US mean implied 3-month rate versus shadow rate estimates
Percentage



Note: Results from Lombardi and Zhu (2014) available until June 2016.
Source: Krippner (2013), Wu and Xia (2016), Lombardi and Zhu (2014) and authors' own calculations.

Figure 9 shows that there is a large discrepancy between our mean implied 3-month rate and the results obtained by WX for the US, similar to what we have observed for the euro area. In the period 2011 until mid-2013 it hovered just under -1%, while both our indicator and the shadow rate by KR fell to levels around -5%. Only after mid-2013 did some convergence in the results found by WX and KR and our approach emerge, as the former fell to levels around -3% and the latter two increased. From mid-2014 onwards, WX's shadow rate starts increasing again, albeit at a slower pace compared to the KR shadow rate, in anticipation of policy rate lift-off by the Fed. In a commentary paper, Krippner (2015) attributes the difference in results across studies to differences in methodologies, specifically the fact that WX is based on a three-factor model, whereas KR uses a two-factor model. Krippner argues that shadow rates found in three-factor models are not robust with respect to the choice of the level of the ELB, whereas two-factor models are. While acknowledging that three-factor models perform better in fitting observed yields, he argues that these gains are relatively small compared to two-factor models and do not outweigh the loss in robustness of the shadow rate.

Finally, Figure 9 shows that the correlation of our indicator with the results found by Lombardi and Zhu (2014) for the US is low, similar as what we have observed for the euro area. Interestingly, the interest rate constructed by Lombardi and Zhu (2014) displays a tendency to converge back to zero over time. One potential explanation for this is that changes in the Federal Reserve's balance sheet are key and explicit contributors to their shadow rate. Thus, once the central bank balance sheet stops expanding, the shadow rate automatically returns to zero (ceteris paribus). For example, this can be observed from mid-2011 until mid-2012, when QE2 was finalised and QE3 was not yet announced.

To conclude, against the backdrop of the ELB for policy rates becoming binding, different authors have developed different instruments to gauge the effective stance of monetary policy with non-standard measures in place. Whereas all approaches confirm that central banks have succeeded in providing significant additional monetary policy stimulus beyond the ELB, approaches disagree about the exact level of monetary policy accommodation provided over time. In terms of its level and correlation, our indicator is most closely associated with the results by KR, even though large discrepancies arise when lift-off of the policy rate from its ELB is being anticipated. Our indicator is unique, in that it is the only indicator that reflects that non-standard measures can be used to provide monetary policy accommodation even when policy rates are no longer at their ELB, given the enduring impact of non-standard measures on the term premium. As a consequence, we anticipate an increasing divergence between our results and those of other studies, should market participants expect an increase in the ECB policy rates from their ELB, while other non-standard monetary policy measures that are focussed at lowering longer-term yields remain in place.

5. Applications

In order to assess how our implied 3-month rate functions as an indicator for the monetary policy stance, we describe in this section two applications inspired by the discussion by Lombardi and Zhu (2014) on the usefulness of their shadow rate. First, we analyse how our indicator performs in a Taylor type rule analysis. The Taylor rule indicates how the monetary stance relates to the 'required' stance according to macroeconomic fundamentals. Such a policy rule is often used in the theoretical and empirical literature as a 'normative' benchmark, which prescribes whether monetary policy is optimal in stabilising inflation and output. The Taylor rule is usually determined by assumed values of the natural interest rate and the response of the central bank to deviations of expected inflation from target and output from potential. Second, we show the use of our indicator in a standard VAR model for monetary policy analysis.

5.1 Empirical Taylor rule

An empirical Taylor rule is estimated by including a lagged interest rate term, thereby allowing for interest rate smoothing (as in Hofmann and Bogdanova, 2012). This is a forward looking Taylor rule, which assumes that the Eurosystem reacts to inflation four periods (one year) ahead. The specification of the empirical Taylor rule is given by,

$$i = \rho \, i_{t-1} + (1-\rho) \, [\, \alpha + \beta_\pi (\pi_{t+4} - \pi^*) + \beta_y \, y_t \,] + \varepsilon \qquad \text{(Model 1)}$$

with i the MRO rate, π_{t+4} the inflation rate one year ahead[12], π^* the inflation objective and y_t the current period output gap.[13] To take into account endogeneity between the policy rate and the regressors, the model is estimated by GMM, using four lags of each explanatory variable as instruments. The model is estimated with quarterly observations covering 1999-2016Q3 and (Newey-West) heteroscedasticity and autocorrelation consistent estimators. Note that our estimates are subject to the critique by Orphanides (2001) that policy-rule parameter estimates based on ex post data can provide biased descriptors of historical reaction functions compared to estimates based on real-time data (specifically on the output gap which is often subject to data revisions due to uncertainty on potential output and mismeasurement of GDP).

The estimation output of Model 1 in Table 1 shows that the parameters are all significant with the right sign. Parameters β_π is close to and parameter β_y is somewhat higher than the parameter values generally assumed in the literature (β_π = 1.5 and β_y = 0.5). The Hansen's J-test for over-identifying restrictions indicates that the set of instrument variables is adequate (i.e. orthogonal to the regressors).

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[12] Gorter et al. (2008) have emphasized the importance of using expectations on output and inflation in estimating reaction functions since policymakers are forward-looking in setting monetary (*inter alia* as a consequence of the sizeable lag in the transmission mechanism of monetary policy. Based on Consensus Economics forecast data they find that the ECB takes into account expected inflation in setting interest rates, whereas the coefficient on realized inflation is not significant. The inflation rate one year ahead we use is the realized HICP inflation rate at t+4. This is a proxy for the forecast of inflation, assuming the one year ahead inflation is perfectly forecasted (we follow Paez-Farrell (2009), who finds that the best fit is produced with t+4).

[13] The output gap is calculated by using an HP-filter over realized GDP-growth in order to assess the trend growth. The gap is then calculated as the difference between the trend and realized GDP-growth.

Table 1: Estimation results empirical Taylor rule

ECB Main Refinancing Rate is dependent variable *i*

	Model 1: Standard Taylor rule	Model 2: Financial stress augmented Taylor rule (money market spread)	Model 3: Financial stress augment Taylor rule (CDS-spread)
Lagged interest rate ρ	0.71*** (0.06)	0.65*** (0.06)	0.77*** (0.03)
Constant α	2.75*** (0.14)	2.78*** (0.24)	6.52*** (0.91)
Inflation gap β_π	1.30*** (0.15)	1.23*** (0.10)	1.07*** (0.10)
Output gap β_y	0.90*** (0.14)	0.89*** (0.10)	0.57*** (0.14)
Lagged financial stress β_φ		-0.01 (0.23)	-1.96*** (0.44)
Observations	67	63	63
R^2	0.92	0.90	0.95
J-stat	4.33	4.74	8.13

***/**/* denotes statistical significance at 1%, 5%, 10% confidence level respectively. Standard errors in parantheses.

In the next equation we extend the standard Taylor rule with a lagged financial stress variable (φ).

$$i = \rho\, i_{t-1} + (1-\rho)\, [\, \alpha + \beta_\pi\, (\pi_{t+4} - \pi^*) + \beta_y\, y_t + \beta_\varphi\, \varphi_{t-2}] + \varepsilon \qquad \text{(Models 2 and 3)}$$

In one variant (Model 2 in Table 1), φ is the money market spread, measured as the log of the difference between the 3 months Euribor rate and the 3 months OIS rate. The estimated parameter β_φ is not statistically significant. In another variant (Model 3 in Table 1) φ is the (log) index of the CDS spread of financial companies in the euro area. In that model, parameter β_φ is statistically significant. This indicates that policy rate (conventional monetary policy) more likely responds to stress in the financial sector than to stress in the money market.

In Models 4, 5 and 6 we include the indicator for the effective monetary stance *s* as dependent variable in the Taylor rule, using quarterly observations covering 2005-2016Q3. This provides an indication to what extent unconventional monetary policy has reacted to the inflation and output gap on the one hand and to financial stress on the other hand.

$$s = \rho\, s_{t-1} + (1-\rho)\, [\, \alpha + \beta_\pi\, (\pi_{t+4} - \pi^*) + \beta_y\, y_t\,] + \varepsilon \qquad \text{(Model 4)}$$

$$s = \rho\, s_{t-1} + (1-\rho)\, [\, \alpha + \beta_\pi\, (\pi_{t+4} - \pi^*) + \beta_y\, y_t + \beta_\varphi\, \varphi_{t-2}] + \varepsilon \qquad \text{(Models 5 and 6)}$$

Table 2: Estimation results empirical Taylor rule

Indicator for effective monetary stance is dependent variable *s*

	Model 4: Standard Taylor rule	Model 5: Financial stress augmented Taylor rule (money market spread)	Model 6: Financial stress augment Taylor rule (CDS-spread)
Lagged interest rate ρ	0.74*** (0.09)	0.74*** (0.04)	0.88*** (0.05)
Constant α	1.78*** (0.37)	3.64*** (1.05)	-1.63 (6.46)
Inflation gap β_π	2.88*** (0.56)	2.61*** (0.37)	3.40*** (1.08)
Output gap β_y	0.17 (0.28)	-0.19 (0.27)	0.65 (0.74)
Lagged financial stress β_φ		-1.61** (0.77)	1.22 (2.58)
Observations	43	43	43
R^2	0.88	0.94	0.94
J-stat	2.68	7.59	5.96

***/**/* denotes statistical significance at 1%, 5%, 10% confidence level respectively. Standard errors in parantheses.

The results in Table 2 show that the response parameters for the inflation gap is significant, while the response parameter for the output gap is insignificant. Moreover, the model fit is lower compared to the conventional Taylor rule (as indicated by the R^2). It suggests that unconventional monetary policy measures – summarized in the implied rate – may have been geared to achieving other goals than conventional monetary policy. It also highlights the shortcoming of conventional Taylor rules as benchmark of the implied (shadow) policy rate.

Parameter estimates of the same model including the financial stress variable (β_φ) show that the effective stance of monetary policy does not respond significantly to the CDS spread of financials (Model 6 in Table 2), but significantly to money market stress (Model 5 in Table 2). The negative sign of the coefficient means that the implied rate decreases when stress increases. It implies that the central bank balance sheet policy is expansionary if stress in the money market rises. It flags that the implied policy rate should be assessed in the context of financial developments, which go beyond traditional macroeconomic developments and developments in the banking sector.

5.2 The implied rate and monetary policy shocks

Following Lombardi and Zhu (2014), we show the use of our indicator of the effective monetary stance in a standard VAR model for monetary policy analysis. In their analysis, the monetary policy stimulus is measured by the interest rates shocks in the model. Lombardi and Zhu show for the US that the use of the federal funds rate during the zero lower bound period underestimates the extent to which monetary stimulus was provided during this period, if the shadow rate is used as yardstick for the monetary policy stance. We apply their framework to the euro area.

For the specification of the VAR model, we follow Bernanke and Blinder (1992), who offer a standard model specification for tracing monetary policy shocks. Their model for the US consists of three key macro variables: the log of real GDP, the log of the real GDP deflator[14], and the federal funds rate. For the euro area, we use GDP growth and the ECB MRO rate as monetary policy variable. Recursive Choleski identification is used to identify the shocks, as is common in stylized monetary policy VAR models. Real GDP reacts with a lag to inflation and monetary policy, while inflation reacts with a lag only to monetary policy. We estimate the three variable VAR model using quarterly data ranging from 1999Q1 to 2016Q3, using two lags.[15] In two separate estimation exercises two monetary policy shocks are extracted, one based on the MRO-rate and one based on our indicator for the monetary stance, the implied short-term interest rate.

Figure 10 shows the two shocks associated with each interest rate separately included in the model. Monetary policy shocks estimated using the indicator of the effective monetary stance show larger effective monetary easing (and contracting) than the shocks based on the MRO rate. The outcomes show that the timing of the (downward, i.e. stimulatory) monetary policy shocks as measured by the VAR model based on implied short-term rate corresponds to most monetary policy shocks identified in the similar model including the MRO-rate. Most visibly this refers to the lowering of the ECB's main policy rate from 425 basis points to 100 basis points in late 2008 and early 2009.

In addition, Figure 10 shows at least four instances since the outbreak of the global financial crisis in late 2007, where the implied short-term interest rate identifies a monetary expansion (denoted by vertical lines) that is not picked up when including only the policy rates. First, in 2008Q1 when, against the backdrop of financial market tensions leading up to the takeover of investment bank Bear Stearns, the ECB decided to provide additional 3-month refinancing operations while at the same time providing supplementary 6-month refinancing operations.[16] Second, in 2010Q2 when the ECB announced the Securities Markets Programme (SMP) to conduct interventions in the dysfunctional markets of Greek, Irish and Portuguese sovereign debt. Jointly, several liquidity providing measures where announced to alleviate stress in the interbank market.[17] Interestingly, the ECB announced in its

[14] In order for nonstationary data to become cointegrated we take the GDP deflator in log levels. This leads to the residuals being stationary and allows us to estimate the VAR model for the euro area.

[15] Lag length criteria tests indicate 2 as the optimal lag length. With two lags the VAR model fulfills the stability condition and the impulse responses are well-behaved.

[16] Before, the maximum maturity of its longer-term refinancing operations had been 3-months, see http://www.ecb.europa.eu/press/pr/date/2008/html/pr080328.en.html.

[17] See http://www.ecb.europa.eu/press/pr/date/2010/html/pr100510.en.html.

press release that these measures were geared at enhancing the transmission of monetary policy through financial markets, while leaving the stance of monetary policy unchanged. However, our model estimates suggest that in spite of these intentions the measures taken by the ECB did have an impact on the effective stance of monetary policy. This result is consistent with Ambler and Rumler (2017), who conduct an event study in which they find that the announcement of the SMP had a significant downward impact on both nominal and real bond yields in the euro area. This study finds similar conclusions for the expansion of the SMP to include the purchase of Italian and Spanish government bonds in 2011Q3, for which our model with the implied short-term rate also identifies an accommodative monetary policy shock (third vertical line in Figure 10). This shock is identified one quarter ahead of a lowering of the policy rate as identified by the model using only the MRO-rate.

Figure 10. Identification of monetary policy shocks [1]
In percent

[1] Shocks are extracted using recursive Cholesky schemes. Estimation is based on quarterly data from 1999Q1 until 2016Q2.The blue line corresponds to the model estimated with the MRO rate. The orange line corresponds to the estimation with the implied short-term rate presented in this paper. The model features the log of real GDP, the log of the GDP-deflator and the MRO or the implied short-term rate.

Note: The first vertical line denotes the ECB's decision to supply additional 3-month longer-term refinancing operations and supplementary 6-month longer-term refinancing operations. The second vertical line denotes the introduction of the Securities Markets Programme for the purchase of Greek, Irish and Portuguese government bonds. The third vertical line denotes the expansion of the Securities Markets Programme with Italy and Spain. The fourth vertical line denotes the announcement and start of the expansion of the Asset Purchase Programme for covered bonds and asset-backed securities with a Public Sector Purchase Programme for government bonds.

Finally, the model with the implied 3-month rate identifies a series of accommodative monetary policy shocks from 2014Q2 until 2015Q1, coinciding with the anticipation, announcement and implementation of several monetary policy measures. This included the introduction of targeted longer-term refinancing operations, a negative interest rate on the ECB's deposit facility, and the

(Expanded) Asset Purchase Programme (EAPP) for covered bonds, asset-backed securities and – as of 2015Q1 – euro area government bonds. The figure shows that this has contributed to a substantial loosening of the effective stance of monetary policy in the euro area that would not have been picked-up by traditional policy rates. Interestingly, the figure shows that later recalibrations of the EAPP, e.g. in 2015Q4 and 2016Q1 when the programme was extended and increased in size respectively (see Subsection 3.2), did add further monetary policy accommodation, but to a lesser extent than the original anticipation and announcement of the programme. This is suggestive of declining marginal returns of the more recent expansions of the Eurosystem's asset purchases compared to its original announcement and implementation.

6. Conclusions and future research

In this paper, we have presented an indicator to assess the effective stance of monetary policy incorporating information on the entire yield curve, thus taking into account the effects that non-standard monetary policy measures exert on longer-term interest rates that are not reflected in the policy rate. To this end, we have presented the implied 3-month interest rate that would be consistent with observed longer-term yields if the fall in yields could not have been caused by a fall in the term premium. The implied 3-month rate provides a simple and intuitive yardstick to assess the degree of overall effective monetary policy accommodation in place. The VAR-analysis presented in our results open up a number of issues for research going forward.

First, follow-up research could investigate the empirical effects of non-standard measures on the effective stance of monetary policy. This could help policymakers in calibrating unconventional monetary policy measures in the future. For example, one could analyse how much the central bank balance sheet would need to be expanded to push the effective stance of monetary policy significantly into negative territory when policy rates are at the effective lower bound. Moreover, it could be analysed to what extent differences in the design of balance sheet policies across central banks can be associated with differences in the impact on the effective stance of monetary policy. Finally, the effect of forward guidance on the monetary stance could be explored, an effect that we have abstracted from in this paper but which is of relevant in other studies that apply shadow rate term structure models as discussed in subsection 4.2.

Second, we have shown that the implied effective stance of monetary policy can differ substantially when applying different methodologies. Clearly, this raises some concerns with respect to the scope to use these indicators for robust policy analysis. It would warrant more theoretical and empirical research into the factors that determine the yield curve and the effective stance of monetary policy. Recent advances in term structure modelling could therefore be usefully employed in this respect, in particular against the backdrop of the ELB.

Finally, if indicators of the effective stance of monetary policy provide a useful tool to deal with the effective lower bound issue in macroeconomic modelling they could, for example, be used in the context of estimating and testing central bank reaction functions that feature in many macroeconomic model and the identification of monetary policy shocks. In such analyses it is important to include financial variables, as our outcomes show that non-standard monetary policy were to an important extent geared to financial market conditions.

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