Interest rate pass-through in the low interest rate environment

The Governing Council of the European Central Bank (ECB) responded to the financial and sovereign debt crisis by reducing key policy rates in the euro area to historical lows. June 2014 saw it shift the interest rate on the deposit facility into negative territory for the first time. Other non-standard monetary policy measures such as the public sector purchase programme (PSPP) and forward guidance aimed, amongst other things, to drive down market rates in the longer-term segment. Monetary policy accommodation caused banks to substantially loosen their lending policies, slashing their lending rates since 2014 to what are now unprecedented lows. Euro area credit institutions were far more hesitant in reducing the interest rates they pay on customer deposits, however. Most of them did not follow money market rates into negative territory, leaving their rates instead marginally above the zero mark.

To date, the negative interest rate environment seen over the past four years has not impacted on long-term interest rate pass-through to bank lending rates. Indeed, the findings of a cointegration analysis indicate that changes in the EURIBOR are being passed through almost in full to bank rates for loans to enterprises over the long run. As for the short-term impact of the non-standard monetary policy measures and the way in which the negative interest rate environment is affecting interest rate pass-through, a more flexible model framework that incorporates time variability into the empirical analysis tends to provide better insights.

Empirical analyses which the Bundesbank has carried out using just such a model framework suggest that interest rate pass-through has been supported by the non-standard monetary policy measures taken since 2011. We find that the changes in monetary policy were passed through in full to bank lending rates up until 2016. The persistence of the period of negative interest rates caused interest rate pass-through to weaken somewhat in 2016, since which time it has been roughly at the same level as it was back in 2011. Bank deposit rates have been anchored just above zero since the middle of 2016, and this will probably have been one major obstacle to further significant cuts in lending rates.

The more protracted the spell of negative rates, the greater the likelihood that the weakening of interest rate pass-through in the short-term segment might, at some point, spill over into the long-term parameters as well. Bear in mind, however, that a weakened pass-through of accommodative monetary policy impulses is taking place against a backdrop of historically low lending rates and that the estimates at the current juncture are implying that interest rate pass-through, though weaker, is still almost complete. Therefore, the level of lending rates is arguably still having a significantly accommodative impact on lending activity.

Introduction

Banks play key role in monetary policy transmission process

Central banks use their monetary policy toolkit to exert influence over variables including general interest rate levels in order to achieve their monetary policy objectives. The primary objective of the Eurosystem is to safeguard price stability in the euro area. Monetary policy measures are transmitted to prices through a variety of transmission channels, and credit institutions play a key role in this regard. For one thing, they are the monetary policy counterparties of the Eurosystem, putting them at the very outset of the transmission process. For another, bank loans still represent a significant source of finance for many non-banks in the euro area, even if funding structures have diversified over recent years to make greater use of equity capital and alternative debt instruments.

Interest rate channel works by influencing the price of loans

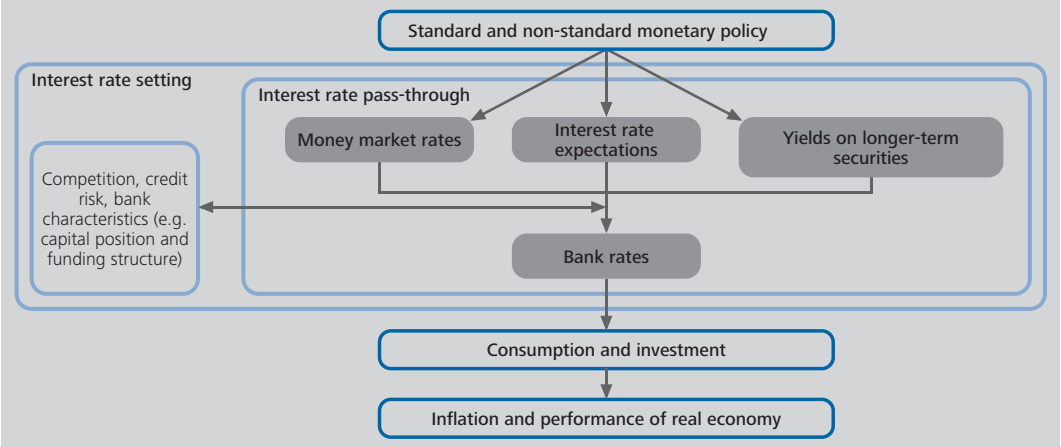
Monetary policy is transmitted through the banking system to influence financing conditions for firms and households. The interest rate channel works on the assumption that monetary policy measures affect market rates directly and banks' lending and deposit rates indirectly.[1] The latter is what is known as interest rate pass-through (see the chart below). This channel is used to transmit interest rate impulses to loan dynamics, economic activity and ultimately the price level. The effectiveness of this channel depends on whether changes in monetary policy rates are passed through in full and without much of a delay.

Euro area interest rate level very low – short-term rates even negative for the most part since 2014

The Governing Council of the ECB responded to the financial crisis of 2008-09 and the European sovereign debt crisis of 2010-12 by cutting key interest rates to historical lows. June 2014 saw it shift the interest rate on the deposit facility into negative territory. Short-term market rates in the euro area moved in tandem with the stepwise reduction of the policy rate level before likewise dropping below zero for the most part. The looming zero lower bound made it increasingly difficult to perceptibly increase the degree of monetary policy accommodation any further by means of policy rate cuts. In an effort to nonetheless achieve continued policy easing, the Governing Council decided to augment its action on the policy rate front by adding a raft of non-standard monetary policy measures so as to exert direct and indirect influence on longer-term market rates

1 See Beyer et al. (2017).

Interest rate channel



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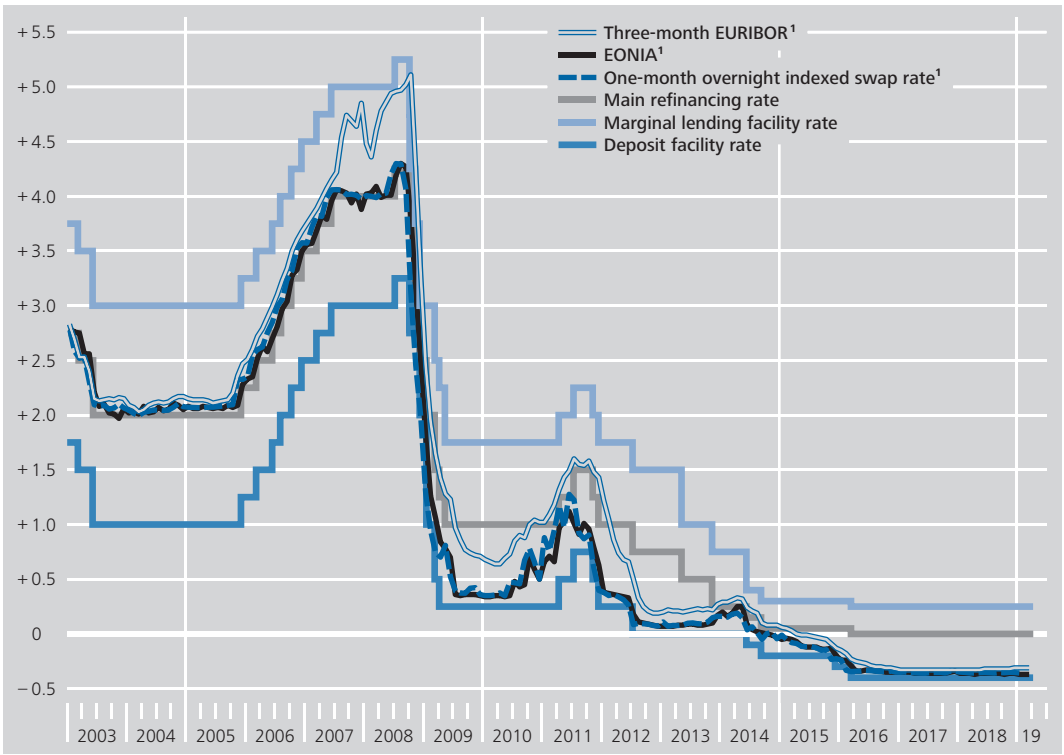
Key interest rates and money market rates in the euro area

% p.a.



Sources: ECB and Thomson Reuters. **1** Monthly averages.
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(see the literature cited on p. 55).[2] What is more, a number of these measures were designed to directly address banks' funding costs.[3]

Low rates affecting banks' rate-setting behaviour

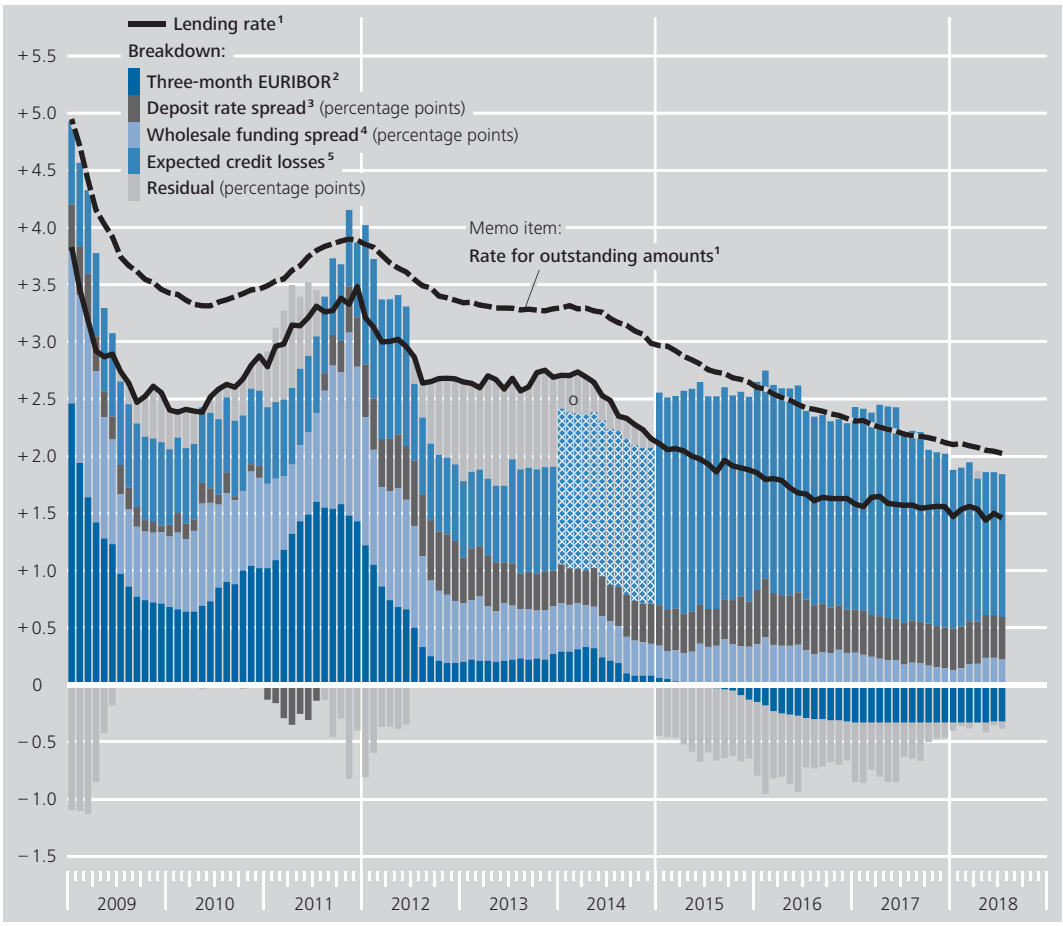
Persistently low interest rates are an unusual backdrop for the euro area's banking system. The introduction of negative rates, especially, saw monetary policymakers embark on a journey into what was largely uncharted territory. Indeed, lacking past experience, they had barely any theoretical or empirical insights into how monetary policy impulses are transmitted through the banking system in periods of negative rates. Because banks adapt their business policy in response to a variety of factors, it is not necessarily the case that the exceptional interest rate setting is a reason, let alone the sole cause, for changes in their business strategy. The financial crisis and the uncertainty and disruption it caused are likely to have left their mark on the transmission process. Much the same can be said for the reform of banking regulations and the prudential regime as part of the implementation of Basel III and the launch of the European banking union. That said, the findings gleaned from the Bundesbank's empirical analyses suggest that rates which persist in low but positive territory, but above all a backdrop of negative rates, have so far not impacted on interest rate pass-through over the long term, even if changes are certainly evident over the short term.

2 These measures included the securities markets programme (SMP) introduced in 2010, the announcement of outright monetary transactions (OMTs) in July 2012, the adoption of forward guidance in July 2013, and the public sector purchase programme as part of the expanded asset purchase programme (APP), which was adopted in January 2015. Details on the individual asset purchase programmes are available at https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html

3 These include, amongst others, the targeted longer-term refinancing operations (TLTRO-I and TLTRO-II) offered from 2014 and 2016, respectively.

Breakdown of the lending rate for new loans to non-financial corporations

% p.a.



Sources: ECB, EBA (Risk Dashboard), Thomson Reuters and Bundesbank calculations. **1** According to the MFI interest rate statistics. **2** Monthly average. **3** Computed as the difference between the aggregated rate on deposits by the private non-financial sector and the one-year overnight indexed swap rate, weighted by the share of customer deposits relative to total borrowing. **4** Computed as the difference between yields on senior bank debt securities (iBOXX) and the five-year overnight indexed swap rate, weighted by the share of bank debt securities used for financing relative to total borrowing. **5** Non-financial corporate sector. Expected credit losses are probability of default (PD) multiplied by loss given default (LGD) for euro area banks (excluding Lithuania, Latvia and Estonia). **o** No EBA data available for 2014. Chart shows the mean between December 2013 and January 2015. As from 2015, EBA data are based on the common reporting framework (COREP) for financial institutions in the EU for the first time.

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Banks' rate-setting behaviour in the low interest rate environment

Interest rate setting before the low interest rate phase: lending rate above a reference rate, deposit rate below

Differently structured though the national banking systems in the euro area may be, they nonetheless share striking similarities in terms of how bank loans and customer deposits are priced. Banks generally gear the rates they set to a certain market rate (reference interest rate).[4] When interest rates are at normal levels, the rate they pay on customer deposits is this reference interest rate less a markdown.[5] This is what usually makes deposits a cheaper means of finance for banks than any other source of funds with a similar maturity. The bank lending rate, by contrast, is usually computed by applying a mark-up to the chosen reference interest rate.[6] This way, banks try to at least cover their business expenses on average. These are made up of items including the cost of capital, expected credit losses, funding costs and operat-

4 EONIA or EURIBOR, for example.
5 This approach to pricing is based on the Monti-Klein model, for example. See Klein (1971); and Monti (1971).
6 See Rousseas (1985); Klein (1971); and Monti (1971).

ing expenses.[7] While a bank's mark-up on capital and expected credit losses will tend to be higher for debtors which are more likely to default, its funding costs and business expenses will depend not on its borrowers' credit quality but above all on the business model it runs.

Key components of lending rates: bank funding costs, credit risk, reference interest rate

Using a model to arithmetically break down the composite lending rate, it is possible to illustrate how each of the cost components affect the lending rates set by banks (see the chart on p. 46). This decomposition process is based on the assumption that banks set their rates for loans to non-financial corporations based not only on a reference interest rate[8] but also on other cost components:

– their funding costs;[9]

– credit risk, measured in terms of expected credit losses in the non-financial corporate sector;

– unexpected credit losses and other costs including, for example, equity costs, which are shown in the chart as the residual, or intermediation margin. This is calculated as the spread between the lending rate and the sum of the cost components (including the reference interest rate).

However, just as this kind of breakdown offers scant insights into the underlying causalities, so, too, would it be wrong to say that the description applies to specific individual banks. Since the breakdown considers lending business to be the sole source of interest income, the findings of this analysis apply primarily to banks running traditional business models.

Bank rates charged for loans to enterprises have not been covering costs since 2014, …

What the breakdown reveals for credit institutions engaged predominantly in classic credit business is that the interest income they earn from loans to enterprises, when viewed from the customary perspective, was insufficient to cover the cost of granting loans, not only during the years of crisis but in and after 2014 as well. It would appear, then, that banks are setting their lending rates for loans to enterprises too low in the negative interest rate environment, meaning that, by rights, their net interest income[10] from traditional corporate lending business ought to be negative.

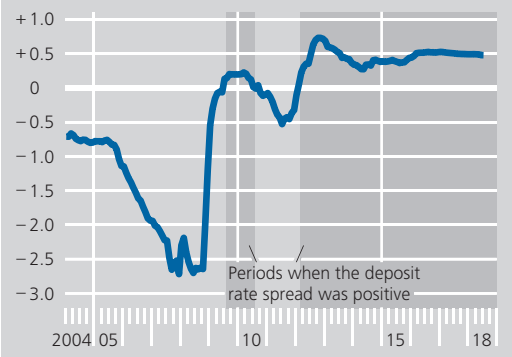
… mainly because the mark-up for expected credit losses in corporate lending business is too small

According to the results actually reported by banks in the euro area as a whole, net interest income has been declining since 2015, but it has not turned negative. This is primarily due to the costs associated with expected credit losses. The customary method of calculation (which is also used here) assumes that banks write off the entire loan if a borrower defaults (exposure at default).[11] Given the scope permitted by banking regulations, this is not necessarily how the banks themselves account for credit losses.[12] An exposure at default of less than 100% reduces the size of the bars representing expected credit losses in the chart on page 46, which means it would lower the costs.[13] In other words, less income would be needed to cover the costs. The optimistic view which banks take when measuring their credit risk is evident both in the empirical literature and, say,

7 In a business-accounting sense, this is how a bank calculates its minimum margins. Banks use this approach as part of their internal accounting operations to set prices in interest-based business which cover their costs. Other sources of bank revenue, such as net commission income, do not feature in this calculation. For euro area banks, net interest income is the chief source of earnings, accounting for roughly 60% of operating profit or loss. See European Central Bank (2017a), pp. 40 f.
8 Three-month EURIBOR is used for the purpose of breaking down the composite interest rate.
9 The calculation used in the chart on p. 46 proxies funding costs as the spread between funding costs and a risk-free rate over a similar maturity. The exercise also assumes by implication that banks in the euro area use customer deposits and bank debt securities as their sole source of funding. These are by far the most important sources of funding for the aggregated banking system in the euro area. In 2018, bank funding in the euro area consisted, on average, of 40% of customer deposits and roughly 14% of bank debt securities.
10 Interest income less interest paid.
11 See European Central Bank (2017b), p. 44.
12 Exposure at default came to a euro area average of 30% in June 2013. See European Banking Authority (2014).
13 Based on the following calculation: expected credit losses = loss given default x probability of default x exposure at default.

Deposit rate spread* in the euro area

Percentage points, monthly data



Sources: ECB, Thomson Reuters and Bundesbank calculations.
* Computed as the difference between the rate for new business for deposits by households and non-financial corporations according to the harmonised MFI interest rate statistics and the three-month EURIBOR.
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the results of the comprehensive assessment of banks in the euro area.[14]

Deposit rates higher than short-term market rates for first time since 2012

In a break from standard business practice, deposit rates have been set above rather than below short-term market rates ever since key interest rates were lowered in response to the financial crisis and particularly in the wake of the fresh round of rate cuts in 2012. In other words, banks are calculating their deposit rates by applying a mark-up, rather than a markdown, to the reference rate (see the above chart).[15] As the rates paid on customer deposits approached zero, banks responded by making only minimal reductions to their deposit rates.[16] Only as from 2013 or thereabouts did the mark-up stop rising and stabilise at a relatively high level. Since 2016, both market and deposit rates have persisted at their respective levels: short-term market rates deep in negative territory and deposit rates still just above zero. The spread between deposit and market rates, having now turned positive, is a relevant cost factor primarily for banks engaged in traditional banking business.

Deposit rate rigidity could impact on lending rates, …

The extent to which this structural change in the pricing of customer deposits (mark-up instead of markdown) impacts on bank lending rates depends on the individual bank's funding structure and business model.[17] Banks tend to actively manage their net interest margin[18] with a view to keeping it as stable as possible over time (margin smoothing).[19] They do so by exercising their market power, but at the same time they are subject to a number of constraints (competition, business-accounting and regulatory requirements). Banks will thus adjust their conditions for loans and deposits so as to achieve their target margins. Hence, there is a long-term correlation between lending and deposit rates which can be proven empirically by means of cointegration analysis.[20]

… although there was a marked fall in lending rates between 2014 and 2016

The way in which margins were shaped altered upon entering a negative interest rate environment, however. Although lending and financing decisions were being taken continuously and simultaneously as before, there was a considerable weakening of the long-term relationship between lending and deposit rates.[21] This was the outcome of widely differing interest rate dynamics: while there was a marked and steady decline in lending rates between 2014 and 2016, sight and savings deposit rates underwent less and less change, the closer they came to the zero lower bound (see the

14 The asset quality review component of the ECB's comprehensive assessment of 130 banks in 2014 resulted in additional provisions of €42.9 billion due to the revised valuation of loans. See ECB (2014a), p. 79. The costs of forbearance are discussed in Caballero et al. (2008). For the euro area, see Homar et al. (2015).
15 Just how crucial a positive deposit rate spread is for German banks, at least, is also evident from the findings of the Bundesbank's survey on the low interest rate setting. See Drescher et al. (2016).
16 See Darracq Pariès et al. (2014). A zero lower bound does not exist in all deposit categories, but it is a major feature for household deposits. Euro area banks certainly do charge negative rates on large-scale sight deposits by households or non-financial corporations. Overall, though, this is only the case in a handful of countries.
17 See Heider et al. (2018).
18 The net interest margin is net interest income relative to the amount of interest-earning assets.
19 See Drechsler et al. (2018).
20 See Sopp (2018).
21 See Sopp (2018). Sopp investigates the interest rate pass-through for deposit rates and uses the borrowing rate as an explanatory variable instead of a reference interest rate. The author measures the change in the long-term relationship over time using rolling regressions.

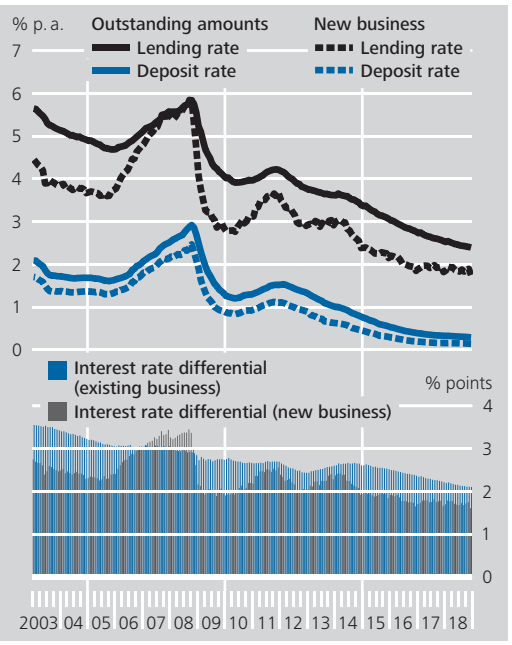
adjacent chart).[22] The declining long-term relationship and the differing dynamics show that, in the euro area, the rigidity of deposit rates up to 2016 was not transmitted to lending rates. These differing developments in lending and deposit rates led to net interest income from banks' traditional lending business in the euro area undergoing a decline since 2014, in particular.

Banks respond by expanding lending and stepping up their maturity transformation so as to offset the decline in net interest income

Euro area banks attempted to counter declining net interest income by making various adjustments to their business policy. While the aggregate interest rate for new bank loans remained more or less constant since 2016 at an all-time low, particularly banks engaged predominantly in traditional deposit and lending business tried to generate additional earnings through a massive expansion of their business volume and increased maturity transformation.[23] For banks, both involve higher risks. Growing credit volumes drive up credit risk, and increasing credit growth tends to reduce the average quality of borrowers.[24] Greater maturity transformation is reflected in higher interest rate risk.[25] The fact that banks assumed the described risks on a larger scale rather than raising the lending rate is likely to have been due to the intense competition in lending business. This is suggested by the results of the Eurosystem's Bank Lending Survey (BLS), which, from 2014 onwards, show the surveyed institutions stating that competition from other banks was the most important reason for the easing of their credit standards.

Lending rates, deposit rates, and interest rate differentials in the euro area*

Monthly data



Source: ECB and Bundesbank calculations. * Volume-weighted interest rates for loans and deposits vis-à-vis the private non-financial sector (according to the harmonised MFI interest rate statistics). Interest rate differential computed as the difference between the lending rate and the deposit rate.

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The BLS also asks explicitly about the impact of various monetary policy measures on net interest income. Around three-quarters of all the participating euro area banks stated that the negative deposit facility rate was weighing on their net interest income (see the chart on p. 50). This statement probably relates, above

BLS: negative deposit facility rate placing a strain on banks' net interest income

22 Darracq Pariès et al. (2014) find a weakened interest rate pass-through between the three-month overnight indexed swap rate (OIS) and the interest rate for sight and savings deposits of the private non-financial sector in the euro area as early as the period of policy rate cuts between 2011 and 2013.

23 Loans granted by savings banks and credit cooperatives to the private non-financial sector between 2014 and 2018 grew at an average annual rate of 3.1% and 4.8%, respectively, while they increased on average by no more than 1.6% and 2.7% annually in the period from 2000 to 2013. As a percentage of total new business, loans to enterprises granted with an initial interest rate fixation period of over five years also saw an increase of 5 percentage points, and the share of loans to households for house purchase with an initial interest rate fixation period of over ten years went up by 15 percentage points. The share of short-term funding through sight and savings deposits rose in the same period by 8 percentage points.

24 See International Monetary Fund (2018), pp. 65 ff.

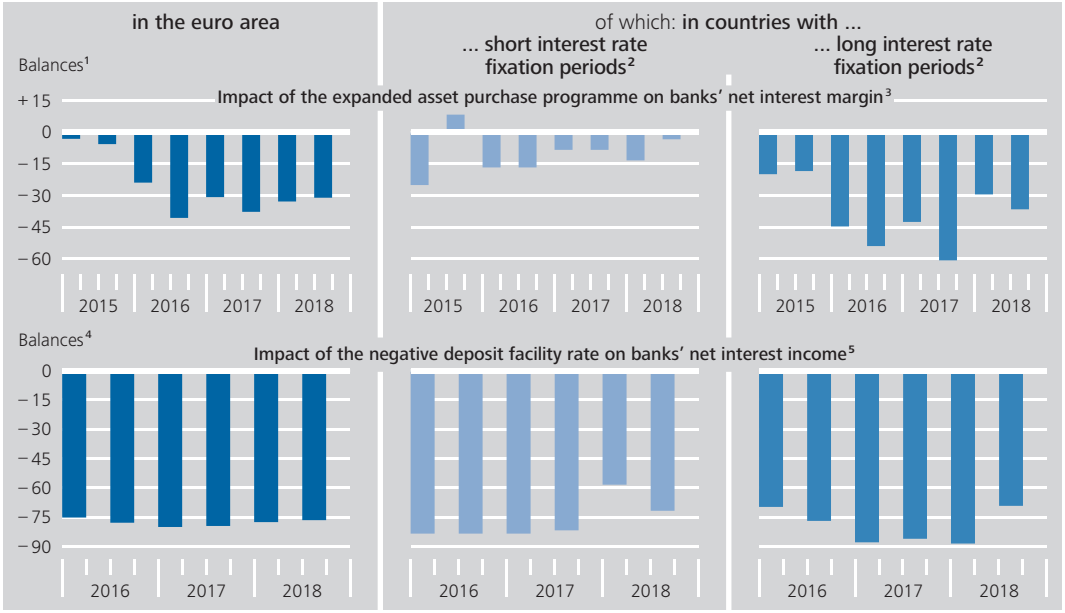
25 Interest rate risk is assessed using a measure proposed by Drechsler et al. (2017):

$$\Delta NIM_t = \alpha + \sum_{s=0}^{s=12} \beta_s \, \Delta Euribor_{t-s} + \epsilon_t.$$

The change in the net interest margin is regressed on the change in the three-month EURIBOR (number of lags = 12 months). For the period from January 2003 to December 2008, this gives a β_{NIM} of 0.1. Drechsler et al. (2017) calculate a β of 0.02 for larger US banks. Hoffmann et al. (2018) estimate a β of 0.04 for larger euro area banks. For the period from 2008, however, there is a β which is negative or close to zero. This means that euro area banks' interest income is reacting much less sensitively than they did as recently as before 2008, which points to heightened interest rate risk. It may be assumed that banks using more maturity transformation to stabilise their income do not hedge their interest rate risk because such hedging would negate the additional earnings.

Impact of monetary policy measures*

As a percentage of all responding banks, end-of-quarter data



Source: ECB. Data according to the euro area Bank Lending Survey. * Impact over the past six months, including direct or indirect effects. **1** Difference of the sum of responses "improved considerably" and "improved somewhat" and the sum of responses "deteriorated somewhat" and "deteriorated considerably" as a percentage of the responses given. **2** "Short (long) interest fixation periods" refers to the arithmetic mean of the responses of the three euro area countries which, according to the MFI balance sheet statistics, show the shortest (longest) interest rate fixation periods in their loan portfolio (short: ES, FI, PT; long: BE, DE, FR). **3** Interest income less interest paid, relative to the amount of interest-earning assets. **4** Balance of the sum of responses "contributed considerably/somewhat to an increase" and the sum of responses "contributed considerably/somewhat to a decrease" as a percentage of the responses given. **5** Difference between interest earned and interest paid by the bank on the outstanding amount of interest-bearing assets and liabilities.

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all, to margin compression resulting from the lower general interest rate level due to the negative interest rate on deposits.[26] The isolated effect of this negative remuneration of excess liquidity is, from a quantitative perspective, of secondary importance for banks' profitability. With regard to the monetary policy asset purchase programmes, under which the Eurosystem has been buying securities on a major scale since spring 2015, only about one-third of banks stated that this was having negative effects on their net interest margin. The asset purchase programmes progressively lowered the longer-term market rates, leading to a marked flattening of the yield curve in the euro area. According to the BLS, this had a negative impact especially on the profitability of those banking systems in the euro area where long interest rate fixation periods have been predominant in the loan portfolio (see the above chart). This does not affect the banking systems of most euro area countries, however.

Interest rate pass-through

Role of reference interest rates

Short-term money market rates can still be used as a proxy for the Eurosystem's interest rate policy

Interest rate pass-through assumes that monetary policy interest rate changes impact on banks' lending and deposit rates through the market rates. Before the financial crisis, the Eurosystem steered the short-term money market rates by regularly providing liquidity at the main refinancing rate. As the short-term money market rates reflect not only the current level of policy rates but also expectations about their future level, they are typically used as a proxy for the monetary policy stance.[27] Besides this, however, the level of money market rates is

26 Specifically, the BLS asks about the direct and indirect effects of the ECB's negative deposit facility rate on net interest income, irrespective of whether or not the bank concerned holds excess liquidity.

27 Money market rates with maturities over one day as well as swap rates like the overnight index swap rate (OIS) typically contain expectations about future monetary policy.

also affected by risk premia, the degree of segmentation in the money market, as well as the liquidity situation in the banking system. These factors became much more important in the financial crisis, resulting in the EURIBOR, for example, containing a non-negligible risk premium for a time. Heightened risk perception in the money market led, in turn, to banks having a greatly increased demand for central bank liquidity, which was met by full allotment[28] in the refinancing operations. The abundant supply of liquidity resulted in short-term money market rates falling below the level of the main refinancing rate and, at times, even closely approaching the deposit rate. Even so, they can still be used in principle as a proxy for the current and expected monetary policy rate. The EONIA, in particular, may still be regarded as the optimum proxy for the Eurosystem's interest rate policy.[29]

Owing to the non-standard measures, the shadow interest rate is used as a proxy for the overall degree of monetary policy easing

The large-scale non-standard measures mean that the overall degree of monetary policy easing, however, can no longer be measured solely by a single money market rate. Along with interest rate policy, these non-standard monetary policy measures determine the monetary policy stance. For that reason, instead of a money market rate or a derivative from it, an artificial interest rate, the shadow rate, has been used for some years now as a proxy for monetary policy.[30]

EURIBOR, in particular, used by banks as a reference interest rate for banking transactions

The choice of the reference interest rate is of particular importance for the analysis of interest rate pass-through. It should, ideally, be a good proxy for monetary policy, on the one hand, and, on the other, be as close as possible to the reference interest rate used by the banks. Up to the financial crisis, the EURIBOR fulfilled both criteria to an adequate extent. Using it made it possible to predict movements in lending rates with a high degree of precision. EURIBOR with a maturity between 3 and 12 months, in particular, is used as a reference interest rate by euro area banks.[31] It has a vital anchor function for the banks' funding. Many financial transactions are linked to it, with high market liquidity in the transactions being a major criterion.[32] EURIBOR with maturities of up to one year is used, for example, in quotes for capital market instruments and as a basic rate of interest for bank bonds with a variable nominal rate of interest. That is why banks use EURIBOR as a reference interest rate for calculating both their funding costs and their lending rates.[33]

Role of market power

Degree of interest rate pass-through determined by competitive intensity in the financial system and banks' market power, …

For lending rates in the euro area, empirical studies find an almost complete interest rate pass-through at least up to the financial crisis, while the pass-through to deposit rates appears to be incomplete.[34] An incomplete pass-through of changes in reference interest rates might be an indication of oligopolistic structures in the European banking market. Such structures probably tended to become stronger following the financial crisis, especially in national banking sectors that were less concentrated up to that point. This is suggested by calculations of customary measures of concentration in a number of euro area countries.[35] From a theoretical standpoint, such an explanation could be supported by the oligopolistic version of the Monti-Klein model, which shows that the lower the intensity of competition in

28 Beginning with the operation on 15 October 2008.
29 Its short maturity (overnight) scarcely permits substantial risks to be priced in.
30 See Deutsche Bundesbank (2017). For more information on the shadow rate, see pp. 61ff.
31 See European Central Bank (2019).
32 Market liquidity for hedging transactions is highest with the three-month EURIBOR.
33 See Kirti (2017).
34 Before the financial crisis, an average of 36% (10%) of a reference rate change was passed through to euro area lending rates (sight and savings deposit rates) within the first month. The degree of long-term interest rate pass-through in the euro area prior to the financial crisis was close to 100% on average for lending rates, compared with around 33% in the case of sight and savings deposit rates. See European Central Bank (2009); as well as Bernhofer and van Treeck (2013).
35 The increase in the Herfindahl concentration index and in the relative importance of the five largest national credit institutions was probably due to resolutions and mergers of banks in the wake of the financial and sovereign debt crisis.

the banking market, the more the degree of interest rate pass-through will decline.[36] This seems plausible, as imperfect competition gives banks substantial market power over their customers. Besides this effect, yet more factors strengthen the market power of the banks.[37] These include the costs of switching to another bank or customers being dependent on a stable bank-customer relationship, say, in the case of small enterprises. Given their strong preference for liquidity, demand for sight deposits is especially high among depositors. Such factors reduce the interest rate elasticity of demand for bank products. The empirical finding that the interest rate pass-through is less strongly marked in the case of deposit rates than it is for lending rates suggests that banks are likely to have greater market power over their depositors than they do over their creditors.[38]

… but cost accounting, interest rate volatility and interest rate expectations also play a part

In addition, banks' cost calculations influence movements in bank interest rates. This may be due to the costs of adjusting prices (menu costs)[39] if banks are slow to adjust their interest rates or do so incompletely following changes to the reference rates. Costs are reduced if interest rates are not adjusted continuously, but rather in stages whenever the change in the reference rate and, therefore, the deviation from interest rates on existing loan agreements has reached a certain magnitude.[40] Moreover, the stickiness of bank interest rates depends positively on the volatility of the market and policy rates.[41] Firmly anchored interest rate expectations and a well-communicated monetary policy therefore encourage a rapid interest rate pass-through.

Implications of a change in the mark-up for interest rate pass-through

In the empirical literature,[42] both a widening of the spread between the bank interest rate and the reference interest rate (the mark-up) and weaker correlation between the two variables are often interpreted as indicators of weaker interest rate pass-through.[43] In the euro area, the mark-up between the lending rate[44] and the three-month EURIBOR has indeed risen considerably since the end of 2008, having shown an almost continuous decline prior to this (see the chart on p. 53).[45]

Spread between lending rate and reference interest rate considerably wider since end-2008, …

However, such a rise does not directly indicate a change in interest rate pass-through. First, in the context of an incomplete[46] pass-through, the mark-up is not necessarily constant, but varies over the interest rate cycle: when interest rates go up, the lending rate rises less sharply than the reference interest rate. The two interest rates thus converge, meaning that the mark-up becomes smaller. Conversely, when interest rates go down, the mark-up increases because a decline in the reference interest rate is likewise not fully passed through to the bank

… which does not necessarily imply a change in pass-through because, first, the lending rate does not mirror increases in the reference interest rate immediately and in full, …

36 See Freixas and Rochet (2008). For an empirical analysis for the euro area, see van Leuvensteijn et al. (2008).
37 See van Leuvensteijn et al. (2008); as well as Klemperer (1987).
38 With regard to the market power of banks over their depositors, see Drechsler et al. (2018); Drechsler et al. (2017); as well as Borio et al. (2017). On the stickiness of deposit rates, see, for example, Hannan and Berger (1991); Driscoll and Judson (2013); as well as Sander and Kleimeier (2004).
39 These might be the costs of preparing new price lists, as well as information and organisational costs.
40 See Hofmann and Mizen (2004); as well as de Bondt et al. (2005).
41 See Borio and Fritz (1995).
42 See the overview of the literature on pp. 67 f. for a summary of the short and long-term pass-through in the euro area.
43 See, inter alia, Hristov et al. (2014); Illes et al. (2015). From a monetary policy perspective, it is the pass-through estimations for lending rates that are particularly interesting since they translate directly into consumption and investment decisions. As a key component of the cost of borrowing, deposit rates influence how banks decide to set their interest rates. The analyses presented in the literature and in this article therefore focus on lending rates.
44 Aggregate interest rate for new bank loans across all loan segments according to the harmonised MFI interest rate statistics.
45 The banks participating in the BLS mainly attributed the decrease in the spread between the lending rate and the market rate since 2013 to the intense competition in lending business in the euro area.
46 The way in which the mark-up is calculated means it can only be considered as the degree to which interest rates are passed through in the short term, i.e. the change in the bank interest rate in the month in which the reference interest rate changed. As explained in footnote 34, this pass-through was also incomplete before the financial crisis.

lending rate. This was demonstrated clearly when, after interest rates were slashed in the wake of the financial crisis, the lending rate followed suit to only a limited extent.

… second, the mark-up between the lending rate and funding costs did not show an unusual degree of expansion, …

Second, the development of the mark-up looks different if it is calculated using the average funding costs[47] of banks rather than the reference interest rate (see the adjacent chart). When calculating the mark-up between the lending rate and the funding costs, no increase is evident after the financial crisis as opposed to before it. On the contrary, after the financial crisis, the mark-up first declined strongly and then recovered gradually until coming to rest at more or less its pre-crisis level from around 2015. In the context of banks' average funding costs, it was the zero lower bound on interest rates, in particular, that prevented the mark-up from increasing more sharply. The evidence that the mark-up expanded therefore seems to be based purely on the choice of the reference interest rate as the reference variable for the calculation.

Mark-up for lending rates in the euro area*

Percentage points, three-month moving averages

Sources: ECB, Thomson Reuters and Bundesbank calculations. **1** Volume-weighted interest rate for new business for loans to the euro area private non-financial sector according to the harmonised MFI interest rate statistics. **2** Volume-weighted composite cost-of-borrowing indicator for euro area banks. This comprises deposits by the private non-financial sector (new business), deposits by the public sector, deposits by other financial institutions, bank debt securities, and liabilities to the central bank and to other MFIs.

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… and, third, increased risk in a cyclical downturn counteracts the decline in lending rates

Third, if a period of low interest rates coincides with a period of weak economic activity, the increased risk on the borrower side counteracts a drop in bank lending rates.[48] In line with this, the results of the BLS indicate that between 2008 and the end of 2013, borrower-side risks were the main reason for the euro area banks' more restrictive lending policies (see the top chart on p. 54).

Error correction models based on a reference interest rate alone no longer appear to adequately capture pass-through

For these reasons, an expansion in the mark-up would be compatible with both a change and no change in interest rate pass-through. Besides this, it is reasonable to assume that the mark-up is influenced by additional factors beyond those listed above. Interpreting the findings in relation to pass-through therefore requires empirical methods that allow this to be estimated. For example, ex post projections produced using a simple error correction model suggest that models specified in this way may not adequately reflect pass-through at the present time. Prior to the financial crisis, movements in lending rates could be predicted with a high degree of precision using a pass-through model of this kind with just one explanatory variable – the three-month EURIBOR. From 2009 onwards, however, the forecast shows that the actual lending rate increased more strongly than the model for the pre-crisis period implied (see the bottom chart on p. 54). Since the outbreak of the financial crisis, it is evident that the development of bank lending rates can no longer be explained using this reference interest rate alone.

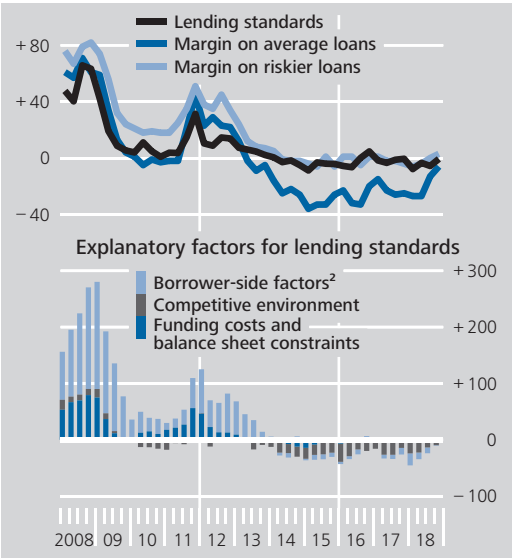
Banks' funding costs decoupled from reference interest rate since the financial crisis

The loss of confidence and increased uncertainty in the interbank market together with the surge in money market rates during the financial crisis meant that banks around the world faced financing difficulties. Banks' funding costs decoupled from movements in the

47 Calculated from all funding sources excluding equity capital, weighted by the respective volume of loans and the respective interest rate for new bank loans.
48 See Borio and Fritz (1995).

Changes in standards and margins for loans to euro area enterprises

Net percentages[1]



Source: ECB. **1** Data according to the Bank Lending Survey; differences of the sum of responses "tightened considerably" and "tightened somewhat" and the sum of responses "eased somewhat" and "eased considerably" as a percentage of the responses given. Net percentages for responses to questions related to explanatory factors are defined as the difference between the percentage of banks reporting that the given factor contributed to a tightening/easing. **2** Included in the BLS questionnaire as "risk perception".

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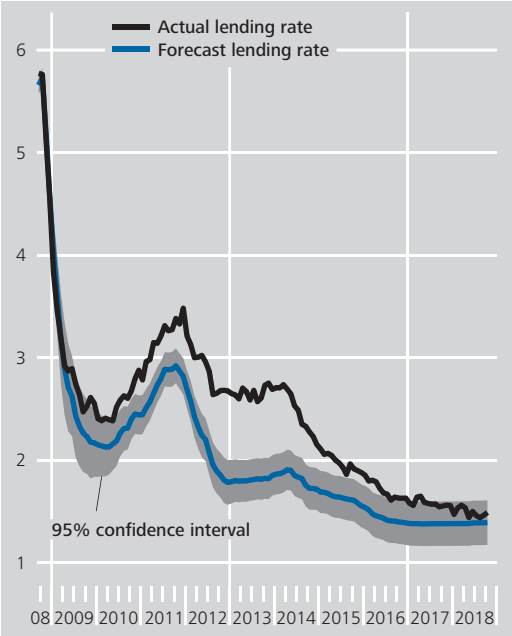
Forecast and actual lending rate for euro area non-financial corporations*

% p.a., monthly data



Sources: ECB and Bundesbank calculations. * Out-of-sample forecasts. Forecast lending rate based on an error-correction model with one explanatory variable – the three-month EURIBOR (for more details, see box on pp. 56 ff.). Estimation period: January 2003 to August 2008.

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EURIBOR during the financial crisis. Monetary policymakers thus began to focus on the average funding costs of banks.[49] This prompted Illes et al. (2015) to use the average funding costs of banks, rather than a reference interest rate, as an explanatory variable in their empirical analysis of pass-through. In contrast to the estimation using the three-month EURIBOR, the authors find that the lending rates developed as would have been expected on the basis of this indicator prior to the financial crisis, too. This finding suggests that the relationship between the reference interest rate and the funding costs of banks changed during the crisis and this had an impact on the pricing of loans.[50] Although the EURIBOR thus appears to remain an important reference interest rate for banks, it no longer seems to capture all the information that determines banks' funding costs and, ultimately, the lending rate.

Long-term relationship between lending rate and reference interest rate only evident when risk measure is added

A cointegration analysis performed as part of an error correction model that includes a reference interest rate as an explanatory variable produces a similar result. It shows no significant long-term relationship between the interest rate for new bank loans to enterprises and the three-month EURIBOR in the entire period spanning the last 15 years. Empirical tests for the existence of a structural break point to such a break during the sovereign debt crisis. However, if a measure of risk is added to the model – in this case, the sovereign risk premium[51] – a significant long-term relationship between the three relevant variables becomes evident for the entire period (see the box on pp. 56 ff.).

49 For example, amongst other things, two series of targeted longer-term refinancing operations (TLTRO-I and TLTRO-II) were introduced in 2014 and 2016 to improve funding conditions for euro area banks. See European Central Bank (2017c).

50 See Holton and Rodriguez d'Acri (2015).

51 The sovereign risk premium is calculated as the difference between the yield on a ten-year government bond and a risk-free interest rate (overnight indexed swap rate) for the same maturity. It includes country-specific credit risk, "flight-to-quality" effects and liquidity premiums. See European Central Bank (2013), p. 90. A similar approach using a sovereign risk premium as an additional explanatory variable in an error correction model can be found in European Central Bank (2017b), p. 17 and in European Central Bank (2013), p. 90.

The coefficient of the long-term pass-through of changes in the reference interest rate is just over 80% for lending rates for enterprises. Pass-through is thus almost complete. By contrast, this long-term relationship cannot be proven empirically until 2010. By including the sovereign risk premium, the model would be misspecified until the start of the sovereign debt crisis.

Risk influences pass-through, especially in times of crisis

Certain risks appear to affect pass-through, especially in times of crisis, while they are less significant in other phases. During the financial and sovereign debt crisis, these risks were mainly liquidity and counterparty risk (of banks as well as sovereigns, enterprises and households). This was compounded by price drops in individual real estate markets and the crisis of confidence in the banking system. These risks had an impact on the level of lending rates, which monetary policymakers factored into their decisions.

Analyses of pass-through at current end require estimation methods containing time-varying parameters

The results of such cointegration analyses, which have been expanded to include a risk measure, provide valuable insights into the long-term equilibrium relationship between the reference interest rate used by the banks and the bank lending rate. Conversely, if the focus is on the impact of non-standard monetary policy measures and the repercussions of the negative interest rate environment, it makes sense to adopt a more flexible model framework that allows for time variability in economic interrelationships.[52]

Pass-through in periods of non-standard monetary policy

At the outset of the financial crisis, the Governing Council of the ECB introduced various non-standard monetary policy measures, …

Since the financial crisis broke out in 2008, the Governing Council of the ECB has adopted a raft of new monetary policy measures. Among these measures were negative interest rates for the deposit facility and various non-standard monetary policy programmes, not to mention the increasing use of forward guidance. Amongst other things, the Governing Council attempted to push down yields at the long end of the yield curve using non-standard monetary policy measures.[53] These included, in particular, the public sector purchase programme (PSPP) as part of the expanded asset purchase programme (APP), which was adopted in January 2015 (see the chart on p. 60). The empirical literature suggests that the announcements about the programme alone had a direct impact on the market.[54] According to estimations by Altavilla et al. (2015) and Andrade et al. (2016), announcements regarding the APP, which saw the purchase of government bonds with maturities of between 2 and 30 years, lowered yields on ten-year government bonds in the euro area by 30 to 50 basis points. Eser et al. (2019) identify similar effects. They also look at the impact of the net purchases under the PSPP up to the end of 2018 and estimate that these purchases reduced the yield on ten-year euro area government bonds by 100 basis points.

… which increasingly saw the yield curve shift downwards and flatten out

The fact that the yield curve shifted downwards repeatedly, as well as flattening out, was due in large part to the Eurosystem's non-standard monetary policy measures. In 2016, yields on bonds of the Member States with the highest credit rating (AAA), even including those with a maturity of up to 10 years, were in negative territory (see the chart on p. 60). Since then, they have increased again somewhat. Nonetheless, they still remain close to their historical lows. Other factors such as political events undoubtedly also affect the yield curve.[55]

52 The error correction model already provides initial indications of changes in pass-through in the recent past. Estimates with rolling ten-year windows throughout the whole observation period show that short-term pass-through of changes in the reference interest rate has dwindled of late.
53 See Deutsche Bundesbank (2016).
54 See Krishnamurthy et al. (2017); Georgiadis and Gräb (2016); Altavilla et al. (2014).
55 For example, the Brexit referendum in the United Kingdom on 23 June 2016 is likely to have been accompanied by a decline in the yields on government bonds issued by euro area countries with the highest rating. See Deutsche Bundesbank (2018), p. 38.

Long-term interest rate pass-through from the perspective of an error correction model

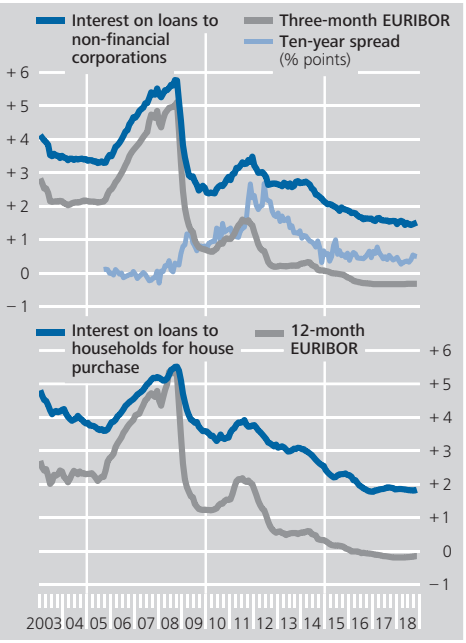
Single-equation error correction models (ECM) are well suited for an empirical analysis of long-term interest rate pass-through. These have been used time and again in the past due to their intuitive interpretability (see, inter alia, de Bondt (2005)). The ECM approach used is given, in general, as follows:

$$\Delta br_t = \sum_{j=0}^{p} \gamma_j \Delta mr_{t-j} + \sum_{k=1}^{p} \delta_k \Delta br_{t-k} - \alpha(br_{t-1} - \beta mr_{t-1} - \mu) + \varepsilon_t$$

br_t denotes the interest rate for new bank loans and mr_t the reference interest rate.[1] The reference interest rate should approximate the banks' marginal funding costs.[2] The coefficient γ_0 shows the degree to which a change in the reference interest rate in period zero is passed through to the bank lending rate within the same period (immediate pass-through).[3] A highly positive value[4] for γ_0 indicates a rapid pass-through. An ECM requires a long-term equilibrium relationship between the relevant variables in levels (term in brackets). This amounts to the same as having a cointegration relationship. Statistical significance tests on the ECM parameters can be used to check whether there is a cointegration relationship between the bank lending rate and the reference interest rate. If α is positive in statistically significant terms, the integrated variables br_t and mr_t are cointegrated with the cointegration vector (β, μ). β represents the coefficient for the long-term interest rate pass-through. It shows the degree to which a change in the reference interest rate is passed through to the bank lending rate in the long-term equilibrium. If the pass-through is complete, there is a coefficient of one. The constant μ denotes all of the time-invariable impacts that cannot be explicitly included in the equilibrium term. The adjustment coefficient α demonstrates by how much a deviation

Lending and reference interest rates

% p.a., monthly



Source: Thomson Reuters and Bundesbank calculations. **1** The ten-year spread is the difference between the average yield on ten-year sovereign bonds in the euro area and the ten-year overnight index swap rate (OIS).

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1 Δbr_t gives the change in the bank lending rate in comparison to the previous period. The model assumes that the lending rate and reference interest rate time series are integrated of order one. The results of the ADF test do not reject this hypothesis.
2 Marginal funding costs are those costs that are incurred when taking on an additional unit of funding.
3 As, later on, only the effects of the unlagged reference interest rates are to be interpreted from the results, $\gamma_j, j > 0$ and δ_k are not outlined in greater detail. Including lagged changes in the bank lending and reference interest rates in the model serves to eliminate potential autocorrelation in the disturbances. The relevant lag length is selected from all lags up to and including lag ten using the Schwarz criterion.
4 A value of one means a 100%, i.e. a complete, pass-through. As the model contains additional time-lagged effects, it is also possible for these coefficients to have values of over one.

from the long-term equilibrium relationship reduces per month.[5]

In a first step, an ECM with the three-month EURIBOR[6] as the reference interest rate is estimated for both categories of lending rate (loans to non-financial corporations and loans to households for house purchase)[7] at euro area level. If no cointegration relationship can be found with this reference interest rate, it is substituted with a longer-term market interest rate.[8] In models for the interest rate pass-through for corporate loans, no cointegration relationship with lending rates can be found in this way, however (see the table on p. 58).[9] This may be due to the fact that these models do not consider a certain factor that is relevant to the interest rate pass-through, namely a risk measure. If the reference interest rate mr_t in the model for the interest rate pass-through for corporate loans is expanded by a spread[10] spr_t as a risk measure, a long-term equilibrium relationship can be found.[11] The expanded model is as follows:

$$\begin{aligned}\Delta br_t = &\sum_{j=0}^{p} \gamma_j \Delta mr_{t-j} + \sum_{l=0}^{p} \theta_l \Delta spr_{t-l} \\ &+ \sum_{k=1}^{p} \delta_k \Delta br_{t-k} \\ &- \alpha(br_{t-1} - \beta mr_{t-1} - \beta^S spr_{t-1} - \mu) + \varepsilon_t\end{aligned}$$

Certain risks appear to affect the interest rate pass-through, especially in times of crisis, while they are less critical in other phases. It would seem that monetary policy has to consider the impact of such factors, expressed here as the risk measure, if it is to bring about a change in the lending rate level.

When modelling the interest rate pass-through for loans to households for house purchase, a reference interest rate with a longer term (12-month EURIBOR) is required. This reflects the fact that, in some countries, loans issued to households for house purchase usually have a long interest rate fixation period.[12] However, a risk measure is not necessary for a significant long-

5 The parameters of an ECM can be estimated in the expanded form of the model. Banerjee et al. (1986) show that, in particular for small samples, it is better to estimate all parameters simultaneously in one equation than to use the Engle-Granger method (Engle and Granger (1987)) as this two-step method entails a risk of distorting the estimate of the long-term relationship. The usual t statistic of the parameter α can be used to check whether there is a cointegration relationship between the bank lending rate and the reference interest rate, both of which are integrated of order one. As, under the null hypothesis, the t statistic of α is not t-distributed for finite samples or asymptotically, the adjusted critical values have to be used. Valid quantiles for the distribution of various sample sizes and the limit distribution can be found in Banerjee et al. (1998). The authors prove that this ECM test for cointegration is, in general, as precise as comparable cointegration tests. However, the latter are more susceptible to certain misspecifications that can have a negative impact on the quality of the test.

6 Surveys of euro area banks revealed that the EURIBOR with a term of between three and 12 months, in particular, is used as a reference interest rate (see European Central Bank (2019)). These reference interest rates can be used as a proxy for banks' funding costs. Many loan contracts and hedging transactions reference the three-month EURIBOR as the underlying.

7 The analysis is based on the lending rate time series from the MFI interest rate statistics which have been collected monthly since January 2003. The estimation period runs from January 2003 to November 2018.

8 12-month EURIBOR as well as yields on sovereign bonds with various residual maturities.

9 Structural break tests indicate a break (during the sovereign debt crisis).

10 A sovereign risk premium, i.e. the difference between the yield on a ten-year sovereign bond and a risk-free interest rate (OIS rate) for the same maturity, is selected here as a general measure of risk. This maturity is singled out because the market for ten-year sovereign bonds is the most liquid. However, the results do not vary greatly from those for spreads with a shorter-term underlying. A similar approach using a sovereign risk premium as an additional explanatory variable in an error correction model can be found in European Central Bank (2017b), p. 17 as well as in European Central Bank (2013), p. 90.

11 Estimations with rolling ten-year windows within the overall observation period also show cointegration relationships between the three variables (bank lending rate, reference interest rate and risk measure) for all sub-periods.

12 Germany and France, in particular, are a case in point.

Results of the pass-through models

Reference interest rate mr_t	Risk measure spr_t	Number of lags in short-term dynamics	Immediate pass-through of reference interest rate γ_0	Immediate pass-through of risk measure γ_0^S	Adjustment speed α (sign. = cointegrated)[1]	Long-term constant[2] μ	Long-term pass-through of reference interest rate[2] β	Long-term pass-through of risk measure[2] β^S	Adjusted R^2
	Aggregated interest on loans to non-financial corporations								
Three-month EURIBOR	.	[3] > 10	.	.	.	.	.	.	.
12-month EURIBOR	.	5	0.60***	.	No cointegration	.	.	.	0.71
Three-month EURIBOR	[4] 10 years	4	0.72***	– 0.02	– 0.18***	1.54(***)	0.84(***)	0.51(***)	0.85
	Aggregated interest on loans to households for house purchase								
Three-month EURIBOR	.	1	0.16***	.	No cointegration	.	.	.	0.62
12-month EURIBOR	.	1	0.13***	.	– 0.04***	2.03(***)	0.73(***)	.	0.68
12-month EURIBOR	[4] 10 years	1	0.18***	– 0.07***	– 0.06*	1.73(***)	0.79(***)	.	0.75

1 Critical values from Banerjee et al. (1998). **2** As the constants and the long-term pass-through coefficients cannot be derived directly from the equation but only as ratios of other parameters, the level of significance is not given directly. In an alternative, direct estimate of these coefficients using the first step of the Engle-Granger method, in all cases shown above, the significance level is at least 1% (given in brackets). **3** If the number of lags required exceeds ten, it is no longer worthwhile estimating the model parameters due to autocorrelation. **4** Difference between the average yield on ten-year sovereign bonds in the euro area and the ten-year overnight index swap rate (OIS). Due to data restrictions, models with a risk measure have been estimated starting from September 2005.

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term relationship.[13] Evidently, in this credit segment, a risk measure is not as key a factor as it is for corporate loans. Either that, or for loans for house purchase, those euro area countries where the size of the risk measure and its variation are too small to have a notable impact on lending rates are predominant.

The long-term pass-through coefficient for the reference interest rate amounts to 0.84 for corporate loans and 0.73 for loans to households for house purchase.[14] The degree of the pass-through is thus high and, at least for corporate loans, almost complete.[15] The coefficient for the long-term pass-through of the risk measure in the model for corporate loans is also significantly different from zero and has an important magnitude. The speed of adjustment is higher for corporate loans than for loans to households for house purchase. The immediate pass-through of changes in the reference interest rate in the first month amounts to 72% for corporate lending rates and only 13% for lending rates for house purchase. By contrast, changes in the risk measure are not passed on to corporate lending rates to a significant extent in the

13 However, a model with a risk measure also has a significant adjustment speed (in this case, only a weak one) and thus shows a cointegration relationship between the bank lending rate, reference interest rate and risk measure. For estimates with rolling ten-year windows, there are sub-periods with and without a cointegration relationship in models with a risk measure as well as those without. Models for more recent time windows are more likely to find a cointegration relationship if they include a risk measure.

14 The absolute size of the constant is not meaningful due to the varying reference interest rates.

15 This finding is in line with the literature on the interest rate pass-through prior to the financial crisis. For loans both to financial corporations as well as for house purchase, the long-term interest rate pass-through is usually found to be high and almost complete (see, for example, de Bondt (2005); Kok Sørensen and Werner (2006); Gambacorta (2008); as well as Marotta (2009)).

same month. It is thus especially important to include a risk measure in order to find a long-term equilibrium relationship between the reference interest rate and the lending rate.

The results of separate estimates for loans with short and with longer interest rate fixation periods are generally consistent with the results on an aggregated level. A risk measure is required for both short-term and long-term corporate loans in order to demonstrate a cointegration relationship. However, it is not required for loans to households for house purchase. For loans with a longer interest rate fixation period, models with longer-term reference interest rates are suitable.[16]

In conclusion, a long-term equilibrium relationship between the bank lending rate and a reference interest rate can be found in the model for the interest rate pass-through for corporate loans at euro area level only if the model is expanded to include a risk measure. In the model for the interest rate pass-through for loans for house purchase, however, a long-term equilibrium relationship exists only between the bank lending rate and a reference interest rate. The degree of the long-term pass-through of changes in the reference interest rate is high in both lending categories under observation and, at over 80%, is almost complete in the case of corporate loans.

16 As loans to households for house purchase with a long interest rate fixation period are issued primarily in Germany and France, an average yield on long-term sovereign bonds of AAA-rated euro area countries is the best fit for the reference interest rate.

Time-varying method needed to analyse short-term pass-through in the current interest rate environment

The Governing Council of the ECB has repeatedly expressed concern that the monetary policy transmission mechanism in the euro area may be impaired.[56] These impairments, as well as the various new monetary policy measures, have probably influenced and also changed interest rate pass-through. Thus, a flexible modelling approach in which the parameters can vary over time is needed. Time-varying vector autoregressive models offer this option. They can be used to examine how interest rate pass-through has changed – during times of crisis, for instance, or also in a low or negative interest rate environment.

Empirical literature suggests weaker pass-through in the aftermath of the financial crisis, …

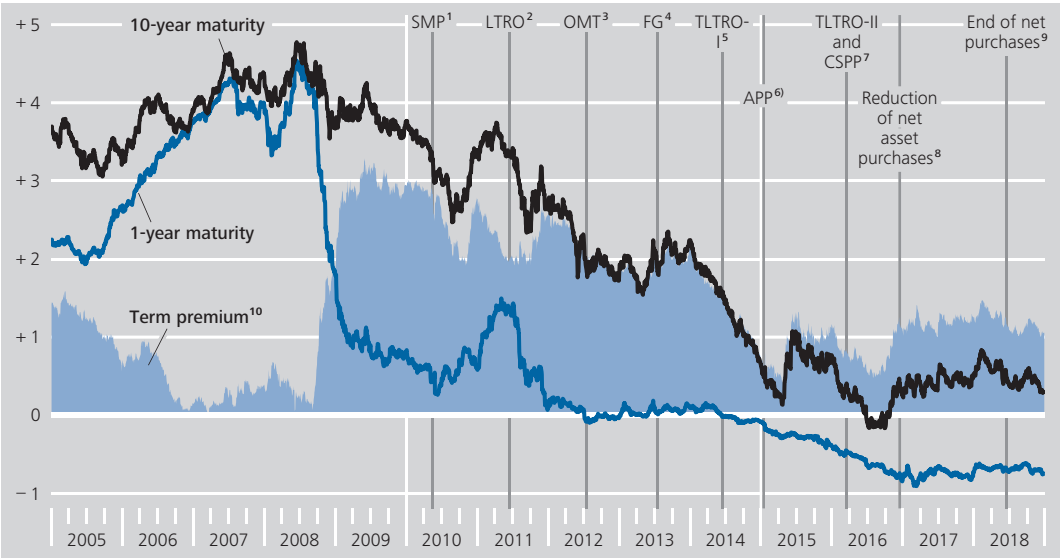
Unlike cointegration analyses[57] (see p. 55 and the box on pp. 56 ff.), vector autoregressive (VAR) models tend to focus on short-term pass-through. Two papers that investigate possible changes in short-term pass-through over the course of the financial crisis are those by Aristei and Gallo (2014) and Hristov et al. (2014).[58] Both studies use VAR models and analyse the period prior to the financial crisis (2003 to 2007) and immediately afterwards (2008 to 2011). They find that short-term pass-through of a monetary policy shock to bank interest rates is less complete in the wake of the financial crisis.[59]

Most studies use short-term money market rates as monetary policy indicators in order to analyse pass-through. However, these only reflect the changes and the level of the key interest rates. Non-standard monetary policy measures, which were mainly added to the Euro-

56 See Draghi (2012); European Central Bank (2010a, 2010b, 2014b).
57 These are based on single-equation error correction models, to which incorrectly assumed cointegration relationships pose problems. VAR models, on the other hand, avoid this potential misspecification (see de Bondt (2005) and von Borstel et al. (2016)).
58 Aristei and Gallo (2014) employ a Markov-switching VAR and Hristov et al. (2014) use a panel VAR for the euro area.
59 In both papers, the monetary policy indicator is proxied by short-term money market rates. Aristei and Gallo (2014) use the three-month EURIBOR and Hristov et al. (2014) use the EONIA.

Short and long-term government bond yields* in the euro area and selected monetary policy decisions

% p.a., monthly data



Sources: ECB and Bundesbank calculations. * Spot rates based on AAA-rated government bonds. Calculated and defined as in https://www.ecb.europa.eu/stats/money/yc/html/index.en.html **1** May 2010: announcement of securities markets programme. **2** June 2011: announcement of longer-term refinancing operations. **3** July 2012: announcement of outright monetary transactions. **4** July 2013: start of forward guidance. **5** June 2014: announcement of first series of targeted longer-term refinancing operations. **6** January 2015: announcement of expanded asset purchase programme (APP); implementation from March 2015. **7** March 2016: announcement of second series of targeted longer-term refinancing operations and corporate sector purchase programme. **8** December 2016: announcement of reduction in monthly volume of net asset purchases under the APP from €80 billion to €60 billion as of April 2017. **9** June 2018: announcement that APP would end in December 2018. **10** Spread between 10-year and 1-year euro area government bond yields (AAA).

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… even following the introduction of the non-standard monetary policy measures during the European sovereign debt crisis

system's interest rate toolkit from 2011 onwards, have had only a limited impact on money market rates. That is why, for a few years now, a hypothetical interest rate referred to as the shadow interest rate has increasingly been used as a proxy for monetary policy. The shadow rate is used, for instance, by von Borstel et al. (2016),[60] who analyse the impact of both conventional and non-standard monetary policy measures.[61] Compared to conventional interest rate changes prior to the financial crisis, they estimate that pass-through of a non-standard monetary policy stimulus to lending rates was less complete during the European sovereign debt crisis. Their analysis covers the period up to 2013 and thus does not yet include the period of negative interest rates or the bulk of non-standard monetary policy measures taken by the Eurosystem.

The negative interest rate environment has barely been examined in pass-through literature to date

To date, there have scarcely been any empirical studies on pass-through in a setting of negative market rates. The empirical study presented in the box on page 61ff. analyses short-term pass-through for the euro area using a Bayesian time-varying VAR model. It looks at how monetary policy stimuli have impacted on bank interest rates for loans to non-financial corporations in the euro area (hereinafter: bank rates). Monetary policy is represented by EONIA or the shadow interest rate. EONIA proxies monetary policy in the model until the first quarter of 2011, after which the shadow interest rate is used. Unlike EONIA, the shadow interest rate reflects not only interest rate policy, but also the announcements and implementation of non-standard monetary policy measures,[62] which became increasingly significant in the

60 They use a factor-augmented VAR model for the euro area and focus on the European sovereign debt crisis (2010 to 2013). They compare this to the period before the financial crisis (2000 to mid-2007).

61 In the model, a conventional stimulus is based on the EONIA. The non-standard monetary policy measures are mapped using various proxies. However, the focus is on the shadow interest rate.

62 For a detailed description of the shadow interest rate, see the box on pp. 61ff.

Short-term interest rate pass-through from the perspective of a BVAR

This box analyses whether the short-term pass-through of monetary policy shocks to the lending rates of euro area commercial banks has changed in recent years due to the low interest rate environment (see Michaelis (2019)). A monetary policy shock is understood to be a change in monetary policy stance (see, inter alia, Sims (1992); as well as Christiano et al. (1999)). The low interest environment in particular could have led to changes in the interest rate pass-through because bank lending rates gradually approached the zero line. That is, there could have been systematic changes in the variances of the shocks and/or in the dynamic effect of these shocks.

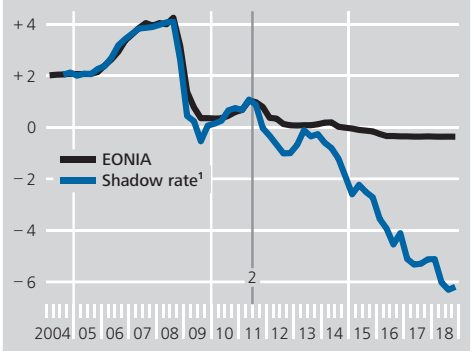
Time-variable VAR with sign restrictions

For the purpose of the analysis, a Bayesian time-variable vector autoregression (VAR) model[1] is used for the euro area, in which three macroeconomic shocks are considered: a monetary policy shock as well as an aggregate demand and an aggregate supply shock. The shocks are identified with the help of sign restrictions. There are two reasons why two cyclical shocks are identified besides the monetary policy shock. First, this prevents these disruptions from distorting the monetary policy shock. Second, the impact of these shocks on the endogenous variables can also be compared over time.

The model contains five variables: real gross domestic product (GDP), the Harmonised Index of Consumer Prices (HICP), a short-term interest rate which describes monetary policy (represented by EONIA or a shadow rate), the bank lending rate for new loans to non-financial corporations and a sovereign bond spread.[2] In the model, EONIA is used as a proxy for the ECB's monetary policy up until the first quarter of 2011. From the second quarter of 2011, EONIA is replaced by the shadow rate (SR) from Wu and Xia (2018) for the euro area.[3] From this point onwards, the two interest rates develop differently: the shadow rate falls by more than EONIA (see the chart below). Although the shadow rate is also a short-term rate,[4] unlike EONIA it covers not only inter-

EONIA and the shadow rate

% p.a., quarterly averages



Sources: Wu and Xia (2018), Thomson Reuters. **1** The shadow rate is based on calculations by Wu and Xia (2018). **2** From Q2 2011, the shadow rate is used instead of EONIA in the time-variable VAR model.

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1 In the VAR model used, the coefficients and the variance-covariance matrices are time-variable.
2 The spread is calculated as the interest rate spread between the synthetic ten-year euro area bond and ten-year German Bunds. Thus, the interest rate spread reflects the movements of the average risk premium in European sovereign bonds. Strong fluctuations in these premia (as seen, for example, during the financial and European sovereign debt crisis) can have an impact on the interest rate pass-through. Thus, they have to be taken into consideration when determining the monetary policy shocks.
3 The results do not change much if the switch from EONIA to the shadow rate takes place earlier (e.g. the first quarter of 2010) or a little later than the second quarter of 2011.
4 The shadow rate is a hypothetical short-term interest rate which would attune without a nominal zero lower bound. It measures the pressure on longer-term interest rates as a result of non-standard monetary policy measures. See also Deutsche Bundesbank (2017).

Sign restrictions*

Shock	Real GDP	HICP	EONIA/SR	Lending rate	Sovereign bond spread
Monetary policy	↓	↓	↑	?	?
Supply (aggregate)	↓	↑	↑	?	?
Demand (aggregate)	↑	↑	↑	?	?

* The sign restriction is imposed for two quarters. "↑" refers to a positive impact, "↓" to a negative impact and "?" to an unrestricted variable.

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est rate policy but also, implicitly, the many non-standard monetary policy measures taken by the ECB's Governing Council.[5] This makes it a more suitable measure than EONIA for estimating the degree of monetary policy easing in the low interest rate environment. In the following, we interpret the monetary policy impulse from the second quarter of 2011 onwards as a non-standard monetary policy shock. The literature, too, refers increasingly to the shadow rate in order to estimate the easing of monetary policy.[6]

The estimation uses quarterly data[7] from the first quarter of 1998 to the fourth quarter of 2018.[8] Real GDP and the HICP are included in growth rates[9] (compared with the previous quarter) and the interest rates in first differences. For all the variables in the estimation the model contains a time lag of one quarter.[10]

The sign restrictions are set according to the usual assumptions in the literature[11] (see the table above).[12] Accordingly, a restrictive monetary policy shock reduces both GDP and the HICP in the short term and increases EONIA/SR. A negative aggregate supply shock lowers GDP and increases prices as well as EONIA/SR. It is assumed that a positive aggregate demand shock increases GDP, the HICP and EONIA/SR. The lending rate and the sovereign bond spread remain unrestricted. Thus, the data determine the sign of these impulse responses. We are chiefly interested in the lending rate.

Results

The impulse responses show that the effects of a monetary policy shock (increase in EONIA/SR by one percentage point)[13] changed over time. The instantaneous pass-through[14] of non-standard shocks to the lending rate appears to have weakened somewhat from the end of 2016 compared to the phase from mid-2013 to the beginning of 2016 (see the adjacent table). Thus, the "lower reliability band", the 16th percentile of the posterior distribution of the

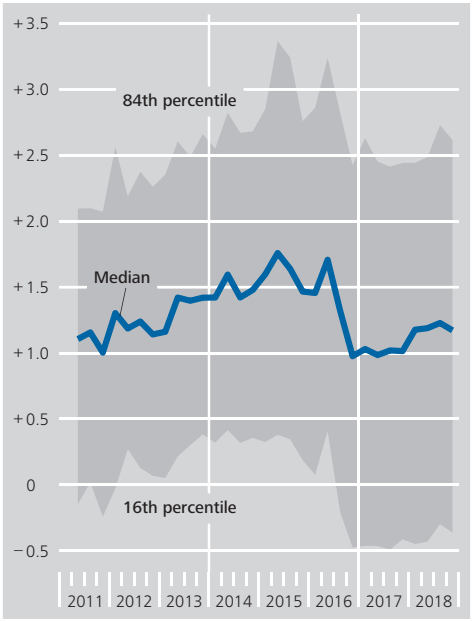
5 Although the ECB Governing Council cut policy rates further between 2011 and 2016, it also rolled out far-reaching non-standard monetary policy measures at the same time. These include the announcement of longer-term refinancing operations in June 2011, the OMT in August 2012 and the APP in January 2015.
6 See Lombardi and Zhu (2014); Wu and Xia (2016); Potjagailo (2017); as well as Filardo and Nakajima (2018).
7 Quarterly values of the monthly time series (HICP and interest rates) are based on averages over the respective months.
8 The training sample uses data from the first quarter of 1998 until the fourth quarter of 2003 and estimates the prior distribution of the model parameters. The actual estimation is based on data from the first quarter of 2004 until the fourth quarter of 2018.
9 GDP and HICP are seasonally adjusted.
10 The length of the time lags is based on the modified harmonic mean estimator proposed by Geweke (1999). An examination of the dynamic stability of the system reveals that none of the eigenvalues is close or equal to one.
11 See Galí et al. (2003); Straub and Peersman (2006); Canova and Paustein (2010); as well as Hristov et al. (2014).
12 The sign restrictions which the impulse response functions must fulfil over a stipulated time period (see the table above) are chosen such that they enable the shock to be attributed plausibly, and on sound economic foundations, to an exogenous monetary policy shock as well as separating it clearly from other shocks.
13 The structural shocks are normalised, which ensures that the shocks remain comparable over time.
14 Instantaneous pass-through is understood here as meaning a period of up to one year.

impulse responses, has been below zero since the end of 2016 and so points to an impulse response that is no longer distinguishable from zero. That said, the interest rate pass-through is roughly comparable with that in 2011. The non-standard monetary policy measures taken from 2011 likely amplified the interest rate pass-through until 2013. By contrast, the pass-through varied little between mid-2013 and the beginning of 2016. During this period, the impulse responses suggest a complete pass-through. It has to be taken into consideration, however, that the reliability bands around the estimated median of the impulse responses are fairly wide.[15]

The calculation of posterior probabilities allows a statistical comparison of the differences in the impulse responses between different periods.[16] Values close to 50% imply only weak differences between the periods under review.[17] The analysis shows that there was actually little difference between the impulse responses of the lending rate from mid-2013 to the beginning of 2016 (see the adjacent table). This is particularly true at the time of the shock and in the subsequent quarter. By comparison, the impulse responses are considerably lower

Impacts of a one percentage point increase in the shadow rate on the lending rate at the time of the shock*

Percentage points



* Impulse response based on a time-variable vector autoregressive model.

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Probability for the differences in impulse responses due to a monetary policy shock to the lending rate*

%

Horizon	Q0	Q1	Q2	Q3
	compared with Q2 2016			
Q3 2011	66	58	53	52
Q4 2012	61	50	40	38
Q2 2013	51	48	47	44
Q2 2015	48	53	55	58
	compared with Q2 2017			
Q3 2011	48	55	66	67
Q4 2013	39	40	50	56
Q2 2014	38	48	59	65
Q2 2015	36	47	61	65
Q2 2016	39	46	58	61
Q4 2016	49	49	51	54

* Posterior probability for differences in impulse responses between Q3 2011, Q4 2012, Q2 2013, Q4 2013, Q2 2014, Q2 2015, Q2 2016, Q4 2016 and Q2 2017 for 0 to 3 quarters in each case. Values above (below) 50% imply smaller (larger) impulse responses at the first point in time than at the comparative point in time (Q2 2016 or Q2 2017).

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15 From mid-2013 until the beginning of 2016, these are between roughly 0.3 and 3.3 percentage points at the time of the shock in period zero. The reliability bands refer to the 16th and 84th percentile of the posterior distribution of the impulse responses.

16 The ratio of the Markov Chain Monte Carlo drawings between two time periods is calculated. The points in time (fourth quarter of 2013, second quarter of 2014, etc.) are selected at random. They represent the different macroeconomic conditions. The comparative point in time is not chosen in 2018, as the points in time at the current end of a sample potentially suffer from somewhat higher estimation uncertainty.

17 Values above (below) 50% imply lower (higher) impulse responses in the second quarter of 2014, for example, than in the second quarter of 2017.

from the end of 2016.[18] In addition, it can be seen that the impulse response in 2017 hardly differs from that in 2011 at the time of the shock and immediately thereafter. The values are close to 50%.

In order to analyse the quantitative importance of the respective shocks, the variances of the forecast errors are decomposed.[19] Demand shocks explain most of the variation of GDP. By contrast, supply shocks are most relevant for price variations. Monetary policy shocks in particular are the driving force behind the lending rate, although their importance for the lending rate changed over time. In 2017, this shock is far less important to the lending rate than in the preceding years. It already lost considerably in importance in the second half of 2016 compared with the first half of the year. On the other hand, the explanatory power of the unidentified shocks with regard to the lending rate increased. These cover all the remaining structural shocks such as a risk premium shock.[20] Thus, the results of the variance decomposition also point to a weaker interest rate pass-through from the end of 2016.

18 This can be seen in the table from the fact that the values for the comparison of the fourth quarter of 2016 with the second quarter of 2017 are close to 50%, while the previous values of the comparisons (up to the fourth quarter of 2013) with the second quarter of 2017 are significantly lower.
19 In contrast to the impulse responses, the decomposition takes account of the estimated standard deviations of the shocks.
20 This is derived from the difference vis-à-vis the sum of the identified shocks. The shocks identified here include demand and supply shocks as well as the monetary policy shock.

euro area as of mid-2011.[63] Therefore, in the following, monetary policy stimulus is interpreted as a non-standard monetary policy shock from this point in time onwards.

Estimates indicate pass-through was initially stronger, before weakening as of the end of 2016

The model estimates show that pass-through has changed over recent years. From mid-2011 onwards, i.e. with the increasing use of non-standard monetary policy measures, pass-through initially increased. It rose until mid-2013 to a level indicative of complete pass-through. From mid-2013 until the beginning of 2016, pass-through remained virtually unchanged at this high level. The longer the negative interest rate environment has lasted, especially since the end of 2016, the weaker the effect of a non-standard monetary policy shock on the lending rate has been.[64] In parallel, at the start of 2017, the explanatory power of non-standard monetary policy shocks for bank rates also declined. By contrast, the explanatory power of unidentified shocks in the model increased. These include, inter alia, shocks to risk premia. Taken together, this indicates that pass-through was supported by the implementation of non-standard monetary policy measures and that monetary policy shocks were passed through in full to bank lending rates. Approximately one and a half years after the launch of the PSPP at the beginning of 2015, pass-through then weakened somewhat. Nevertheless, it is roughly comparable to pass-through in 2011, i.e. when non-standard monetary policy measures were first introduced.

63 Examples of non-standard monetary policy measures announced by the ECB since mid-2011 include longer-term refinancing operations (LTROs) in June 2011, OMTs in August 2012, and the APP in January 2015. Furthermore, estimates show that the non-standard monetary policy measures since mid-2011 are likely to have increasingly influenced the shadow interest rate (see de Rezende and Ristiniemi (2018)).
64 These changes over time are evident, on the one hand, from the uncertainty bands of the impulse responses, and, on the other hand, from the calculation of the probability of statistical differences between the impulse responses at different points in time (see the box on pp. 61ff.).

Analysis does not allow conclusions to be drawn on the necessity of the complete set of non-standard monetary policy measures taken by the Eurosystem

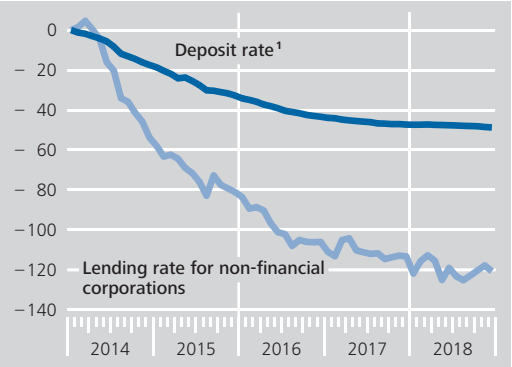
As the individual monetary policy measures are not modelled separately as shocks, and the shadow interest rate instead represents the entirety of the measures, the analysis does not allow conclusions to be drawn on whether the complete set of non-standard monetary policy measures was necessary to achieve this transmission of monetary policy stimulus. In the model specification used here, it is not possible to isolate and assess the impact of every single monetary policy decision.

Deposit rates hovering at the zero mark may have contributed to banks not lowering their lending rates any further since 2016

At first glance, it may be surprising that pass-through has weakened since the end of 2016 in spite of the continued extensive monetary policy measures. Although the ECB Governing Council announced at the end of 2016 that it did not intend to make its stance any more accommodative, its monetary policy stance has remained clearly expansionary. At roughly the same time, from around mid-2016, the protracted period of massive cuts in lending rates by banks that started in March 2014 came to an end (see the above chart). Bank deposit rates, which have also hovered marginally above the zero mark since the middle of 2016, may have been a major factor preventing further significant cuts in lending rates, which would have been accompanied by further falls in net interest income.[65]

Cumulative change in euro area lending and deposit rates since the start of 2014*

Basis points



Sources: ECB and Bundesbank calculations. * New business according to the harmonised MFI interest rate statistics. 1 Interest rate on deposits by households and non-financial corporations.
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Conclusion

Risks have influenced pass-through since the financial crisis

Before the financial crisis, the Eurosystem steered short-term money market rates by regularly providing liquidity at the main refinancing rate. Monetary policy stimuli were transmitted via the money market and capital market rates to the lending and deposit rates of banks. During the financial crisis, uncertainty and the loss of confidence in the interbank market were among the factors which led to the reference rates being biased upwards. As a result, it was no longer possible to identify any long-term relationship between the lending rate and the reference rate. Certain risks appear to affect pass-through in times of crisis in particular, while being less significant in other periods. This was the case, for example, for the effect of liquidity risk and counterparty risk on bank lending rates in the euro area. Monetary policymakers appeared to factor this into their decisions. Empirical tests carried out by the Bundesbank confirm the impact of these risks on pass-through in the aftermath of the financial crisis. For example, since 2010 there has been a long-term correlation between the lending rate, the reference rate and a sovereign risk premium.

Since 2012, deposit rates are no longer lower than money market rates, but higher

The Governing Council of the ECB responded to the financial and sovereign debt crisis by reducing key policy rates in the euro area to historical lows. June 2014 saw it shift the interest rate on the deposit facility into negative territory for the first time. Other non-standard monetary policy measures such as the PSPP and forward guidance aimed, amongst other things, to drive down market rates in the longer-term segment. Monetary policy accommodation caused banks to substantially loosen their lending policies, slashing their lending rates as of 2014 to what are now also unprecedented lows. However, euro area credit institutions were far more hesitant in reducing the

65 A similar line of reasoning is also taken by Eggertsson et al. (2019).

interest rates they pay on customer deposits. Most of them did not follow money market rates into negative territory, leaving their rates instead marginally above the zero mark.

Despite static deposit rates, there is no demonstrable change in long-term pass-through

The negative interest rate environment over the last four years has thus far not impacted on long-term pass-through to lending rates. Changes in the EURIBOR are being passed through almost in full to bank rates for loans to enterprises over the long run. By contrast, assessments of the short-term impact of non-standard monetary policy measures and the influence of the negative interest rate environment on pass-through are better made using a more flexible model framework that allows for time variability in economic interrelationships.

Time-variable empirical studies carried out by the Bundesbank using the shadow interest rate as a measure of the degree of monetary policy easing indicate that short-term pass-through has changed in recent years. According to these studies, pass-through was initially supported by the non-standard monetary policy measures taken since 2011 and monetary policy shocks were therefore transmitted in full to bank lending rates. By contrast, during the period of negative interest rates, pass-through weakened somewhat and has since been roughly comparable to its level in 2011. Bank deposit rates persisting marginally above zero since the middle of 2016 may have been the predominant factor in preventing further significant cuts in lending rates.

Short-term pass-through initially improved with non-standard monetary policy measures, but weakened again during the prolonged period of negative interest rates

Short-term pass-through weakening in an environment of historically low lending rates

The more protracted the spell of negative rates, the greater the likelihood that the weakening of pass-through in the short-term segment might, at some point, spill over into the long-term parameters as well. It should be noted, however, that a weakened pass-through of accommodative monetary policy measures is taking place against a backdrop of historically low lending rates and that the estimates at the current juncture imply that the interest rate pass-through, though weaker, is still almost complete. Therefore, the level of lending rates is likely to still have a significantly accommodative impact on lending activity.

Overview of the literature on interest rate pass-through since 2014*

Authors	Countries	Observation period and level	Structural break	Method	Key findings
Altavilla et al. (2016)	Euro area	– July 2007 to Dec. 2015 – Macro	–	VAR	– Bank balance sheet characteristics (capital ratio, share of government bonds held) responsible for heterogeneity in pass-through of conventional monetary policy – Non-standard monetary policy measures lowered lending rates, especially at banks with a high NPL ratio and low capital ratio
Aristei and Gallo (2014)	Euro area	– Jan. 2003 to Sep. 2011 – Macro	Break: Sep. 2008	Markov-switching VAR	– Pass-through to lending rates lower when market rates are highly volatile – Lending rates for NFCs respond more strongly than lending rates for households to changes in market rates
Arnold and van Ewijk (2014)	AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	– Jan. 2003 to Nov. 2013 – Macro	Estimation periods: – Jan. 2003 to Aug. 2008 – Sep. 2008 to Nov. 2013	State space model	– Heterogeneity of government bond yields since financial crisis is the most important factor for heterogeneous lending and deposit rates across euro area countries
Avouyi-Dovi et al. (2017)	DE, ES, FR, IT, GR, PT	– Jan. 2003 to Oct. 2014 – Macro	One or two breaks per country	ECM with time dummies, stochastic volatility model, VAR	– Long-term relation in pass-through of interest rates on customer deposits to lending rates for NFCs weakened in the wake of the sovereign debt crisis – Heterogeneous results across countries – VAR model: deposit rate shock has had weaker impact on unexpected variance of lending rates since 2010
Blagov et al. (2015)	IT, ES, IE, PT	– Jan. 2004 to Dec. 2014 – Macro	–	Markov-switching VAR	– Global risk factors increased lending rates in ES and IT. ES: additional problems in banking sector. IT: additional fiscal problems and contagion effects
Blot and Labondance (2013)	AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	– Jan. 2003 to May 2010 – Macro	Break: Oct. 2008	SUR ECM	– Pass-through less complete since financial crisis – Increased homogeneity across euro area countries
von Borstel et al. (2016)	AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT and euro area	– Jan. 2000 to Dec. 2013 – Macro	Estimation periods: – Jan. 2000 to June 2007 – 2010 to Dec. 2013	FAVAR	– Sovereign debt crisis changed transmission of conventional monetary policy, but not the components of pass-through: monetary policy lowered banks' funding costs, but not their mark-up – Non-standard monetary policy measures had effective impact on pass-through; lending rates fell
Camba-Mendez et al. (2016)	Euro area	– July 2007 to Oct. 2014 – Micro	–	Two-stage panel regression	– Monetary policy measures to reduce volatility in money market and to improve financing terms via covered bonds (CBPP) had positive impact on pass-through (more complete)

* See the footnote on p. 68.
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cont'd: Overview of the literature on interest rate pass-through since 2014*

Authors	Countries	Observation period and level	Structural break	Method	Key findings
Darracq Pariès et al. (2014)	AT, BE, DE, ES, FI, FR, GR, IE, IT, LU, NL, PT	– Jan. 2003 to Dec. 2013 – Macro	Estimation periods: – Jan. 2003 to Aug. 2008 – Sep. 2008 to Dec. 2013	ECM, DSGE model	– Less complete pass-through in IT and ES owing to strained government bond markets and less favourable economic situation – Less complete pass-through for deposit rates in low interest rate environment
Eller and Reininger (2016)	Euro area, DK, HU, SE, GB, CZ, PL, RO	– Jan. 2003 to Dec. 2014 – Macro	–	Panel ECM, VECM for individual countries	– Yields on long-term government bonds influence interest rates for long-term loans – Non-standard monetary policy measures influence lending rates via this relationship
Gambacorta et al. (2014)	IT, ES, GB, US	– Jan. 1989 to June 2013 – Macro	Break: Sep. 2008	ECM	– Break in cointegration relationship between EONIA and lending rates in 2008 – Adding risk variable (NPL ratio and CDS) explains model change
Holton and Rodriguez d'Arci (2015)	Euro area	– Aug. 2007 to June 2012 – Micro	–	Panel ECM	– Incomplete pass-through of money market rates to lending rates since financial crisis: higher government bond yields drove up banks' funding costs – Individual bank characteristics are of importance, especially those which reflect funding difficulties
Hristov et al. (2014)	AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	– Q1 2003 to Q4 2011 – Macro	Break: Q1 2008; estimation periods: – 2003 to 2007 – 2008 to 2011	Panel VAR, DSGE model (financial frictions)	– Pass-through less complete since financial crisis – Weakening of pass-through owing to changed structural parameters of the economic variables and greater structural shocks
Illes et al. (2015a)	AT, DE, ES, FI, FR, IE, IT, NL, PT, DK, GB	– Jan. 2003 to Apr. 2014 – Macro	Estimation periods: – Jan. 2003 to Aug. 2008 – Sep. 2008 to Apr. 2014	Panel ECM	– Misleading comparison between lending rates and monetary policy rates: banks have higher funding costs – Comparison between lending rates and composite cost-of-borrowing indicator: unchanged pass-through since financial crisis
Leroy and Lucotte (2015)	AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	– Jan. 2003 to Dec. 2011 – Macro	Estimation periods: – Jan. 2003 to Sep. 2008 – Aug. 2007 to Dec. 2011	Panel ECM and panel VAR	– Rise in heterogeneity across euro area countries in pass-through for lending rates since the financial crisis – Reasons: strained financial markets, weak economic situation and country-specific financial market structures (competition)

* CBPP: covered bond purchase programme, CDS: credit default spread, DSGE: dynamic stochastic equilibrium model, ECM: error correction model, FAVAR: factor augmented vector autoregressive model, SUR: seemingly unrelated regression model, VAR: vector autoregressive model, NFCs: non-financial corporations, NIRP: negative interest rate policy, NPL: non-performing loan.

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Literature on the negative interest rate environment*

Authors	Countries	Observation period and level	Structural break	Method	Key findings
Amzallag et al. (2019)	IT	– Jan. 2013 to Dec. 2015 – Micro	Dummy variable after June 2014	Difference-in-difference	– Banks' funding structure is an important factor in pass-through of negative interest rates to lending rates – Banks with higher share of deposits charge higher rates on fixed-interest loans for house purchase
Eggertsson et al. (2019)	Euro area, S, CH, DK, JP, DE	– As of 2014 – Macro and micro	–	Difference-in-difference, DSGE model (with ZLB)	– Pass-through impaired for both deposit rates and lending rates since start of NIRP in euro area – NIRP can have contractionary effect on GDP – Cause: NIRP negatively affects banks' profitability
Heider et al. (2018)	Euro area	– Jan. 2009 to Dec. 2015 – Micro	Estimation periods: – Jan. 2011 to Dez. 2015; – Jan. 2013 to Dez. 2015	Difference-in-difference	– Banks are reluctant to pass on negative interest rates to depositors, driving up funding costs (particularly for banks with high share of deposits) – NIRP increases risk taking and lowers lending at banks with a high share of deposits
Horvath et al. (2018)	AT, BE, CY, FI, FR, DE, IR, IT, NL, PT, SL, SK, ES	– Jan. 2008 to Oct. 2016 – Macro	–	Panel ECM	– Complete pass-through only for small-volume loans – Weaker pass-through in sovereign debt crisis; Eurosystem purchase programmes mitigated these adverse effects – Negative interest rate environment has no impact on pass-through
Sopp (2018)	DE	– Jan. 2003 to Dec. 2016 – Macro	–	ECM	– Weakening of pass-through of lending rates to deposit rates since start of NIRP

CBPP: covered bond purchase programme, CDS: credit default spread, DSGE: dynamic stochastic equilibrium model, ECM: error correction model, FAVAR: factor augmented vector autoregressive model, SUR: seemingly unrelated regression model, VAR: vector autoregressive model, NFCs: non-financial corporations, NIRP: negative interest rate policy, ZLB: zero lower bound.

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