The impact of monetary policy on the euro's exchange rate

The monetary policy of central banks is a key determinant of the exchange rate. Although exchange rates are not a target variable of the Eurosystem's monetary policy, the interest rate environment – with monetary policy as one of its major determinants – is of fundamental importance for developments in the euro's exchange rate. After introducing the basic theoretical mechanisms, this article presents a number of empirical studies on the impact of euro area monetary policy on the euro's exchange rate.

Initial indications of a significant relationship between monetary policy and foreign exchange markets are provided by the observation that there is a marked increase in the volatility of bilateral euro exchange rates during the communication of monetary policy decisions. In line with this, many of the largest single-day losses and gains of the euro also have a monetary policy background. Moreover, the exchange rate movements of the euro on days when monetary policy meetings are held are more pronounced than otherwise. This discrepancy appears to have increased yet further over time.

In order to say anything about causality, however, monetary policy impulses first have to be carefully disentangled from other determinants relevant to financial markets and the real economy. In event studies, this is done by looking at interest rates only in a very narrow window surrounding monetary policy announcements. Results of such an event study show that a contractionary monetary policy impulse of the Eurosystem leads directly to a significant appreciation of the euro, although the effect appears to be weaker if the impulse works mainly through short-term interest rates. According to the event study, the impact of monetary policy on the euro's exchange rate has increased over time.

Vector autoregressive (VAR) models are more complex than event studies and model interdependencies between monetary policy and other economic developments. An analysis of this kind suggests for the euro/US dollar exchange rate that the impact of monetary policy over the past few years was considerable even compared with other macroeconomic determinants.

Above and beyond an inherent impulse, however, monetary policy communication can also supply additional information that is likewise of great importance for financial markets. One example of this is the central bank's assessment of the economic situation and outlook. "Information impulses" of this kind work on the exchange rate in a way that is different from direct monetary policy signals. Furthermore, these indirect effects vary depending on the currency against which the euro's exchange rate is defined. Currencies that are perceived more strongly as speculative respond differently from "safe haven" currencies. How the observed partner currency typically responds to variations in investors' risk appetite is therefore a factor.

Introduction

Importance of exchange rates in economic policy

In a globally interconnected world, exchange rates play a major economic role. Not only trade flows, but also international flows of capital are crucially determined by the exchange rates between currencies. For open economies, especially, a depreciation of the domestic currency can, for example, lead – at least in the short to medium term – to price competition advantages, since domestic goods then become cheaper for major trading partners.[1] There is also an attendant downside that mirrors this, however: imported goods become more expensive in relative terms, lowering domestic purchasing power as a result. Along with the depreciation, there is, moreover, an increase – from a domestic perspective – in the value of (external) assets and (external) liabilities denominated in foreign currency. In the case of assets, a depreciation leads to a gain in wealth in the domestic currency.[2] A high level of foreign debt in foreign currency is relevant, above all, for developing and emerging market economies, in which the bond markets are often underdeveloped and bonds are issued in foreign currency, mainly US dollar. The major importance of exchange rates in economic policy calls for an examination of the factors that influence them.

Monetary policy and exchange rates

It is, above all, monetary policy that has a key role to play here. For one thing, central banks have the option to intervene directly in the foreign exchange market by buying and selling.[3] Above and beyond that, however, they exert an indirect influence on exchange rates through their interest rate policy. Although the exchange rate is not a target variable for the Eurosystem, for example,[4] monetary policy measures inevitably have side effects on foreign exchange markets that are transmitted to other countries. Especially a period in which there is a substantial difference in the monetary policy stance of two countries can bring with it marked movements in the bilateral exchange rate. This illustrates how important it is to understand and, as far as possible, quantify the effects on the markets of a monetary policy geared to domestic targets such as price stability.

Theoretical considerations and initial empirical evidence

Exchange rate as a target variable of monetary policy then and now

In the post-war period up to the collapse of the Bretton Woods system in the early 1970s, the monetary policy of even advanced economies was, as a rule, geared to an exchange rate target. One of the chief tasks of central banks was to maintain the peg to the US dollar by means of their monetary policy stance and direct interventions in the foreign exchange market. The progressive liberalisation of cross-border capital flows increasingly restricted the options for shaping monetary policy in this regime, however. If an overly accommodative interest rate policy led to net capital outflows that were not solely temporary in nature, there was a danger of the central bank's US dollar holdings running out because of foreign exchange market interventions. This meant that the central bank had to tighten monetary policy regardless of the economic situation at home and had to follow the objective of upholding the exchange rate peg.

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1 For indicators of price competitiveness and their impact on real exports of goods, see Deutsche Bundesbank (2013) and Deutsche Bundesbank (2016). Deutsche Bundesbank (2013) as well as Deutsche Bundesbank (2016).

2 In the first quarter of 2020, for example, Germany's net international investment position amounted to almost €2.4 trillion (see the International investment position and external debt tables in the Bundesbank's Statistical series https://www.bundesbank.de/en/publications/statistics/statistical-series/statistical-series-international-investment-position-and-external-debt-841806). Of this amount, the share of Germany's external assets denominated in foreign currency was significantly larger than the foreign currency share of external liabilities.

3 The scale of foreign currency reserves held by central banks is also sufficiently large to be able to cause significant exchange rate effects by their use. The International Monetary Fund gives the official foreign exchange reserves of the 149 reporting countries for the first quarter of 2020 as the equivalent of almost US$12 trillion (see https://data.imf.org/cofer).

4 See ECB President Mario Draghi, press conference on 25 July 2019 (https://www.ecb.europa.eu/press/pressconf/2019/html/ecb.is190725~547f29c369.en.html). On this occasion, he stressed that "We have a mandate which is price stability … we don't target exchange rates."

The role of the euro exchange rate in ECB press conferences

Monetary policy impulses are usually identified in the literature as a key determinant of the exchange rate. However, many major central banks, such as the Eurosystem, do not regard the exchange rate as a target variable. This raises the question of the extent to which exchange rate topics play any role at all in monetary policy communication.

One way of answering this question is to examine the ECB's press conferences following monetary policy meetings. However, this is a complex undertaking, as 236 press conferences were held following monetary policy meetings in the period from the ECB's founding in June 1998 to March 2020,[1] and the transcripts of these press conferences contain almost 1.4 million words. This is why so-called text mining approaches are used here.[2] Unlike the analysis of prepared data, which is the norm in economic research, text is unstructured and highly dimensional, especially compared with macroeconomic data. A different approach is therefore required for the analysis of text data. An analysis using methods from the field of machine learning is presented below.[3]

This analysis uses a topic modelling approach that draws on statistical methods to assign topics to individual sentences.[4] These topics consist of a collection of words that occur together at a certain frequency in the examined sentences. In specific terms, a latent Dirichlet allocation (LDA) is estimated.[5] As part of this process, a probability vector over the unobserved ("latent") topics is assigned to each sentence. At the same time, each topic consists of a distribution across all words in the text. A Dirichlet distribution is assumed a priori for the parameters of both distributions. In addition to the parameters for these two Dirichlet distributions,[6] the number of topics to be determined must also be set a priori. Following the literature, this number is set at 40.[7]

However, before the analysis of the text can begin, it must be put into an analysable form. After the html code downloaded from the ECB website was broken down into individual words and sentences, the text was adapted for the analysis as follows:

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1 These are all the press conferences published on https://www.ecb.europa.eu/press/pressconf/html/index.en.html between 9 June 1998 and 12 March 2020, with the exception of those on 13 October 2003 and 26 October 2014, which dealt specifically with a cooperation agreement with the Russian central bank and the comprehensive assessment and thus did not address the Eurosystem's monetary policy.

2 Text-mining approaches are becoming increasingly popular in the area of monetary policy analysis, particularly using the minutes and transcripts of meetings of the Federal Open Market Committee (FOMC), whether it be to measure the impact of different forms of communication on financial markets and the real economy (Hansen and McMahon (2016)), examine the effect of greater transparency on decision-making (Hansen et al. (2018)), determine the Federal Reserve's objectives (Shapiro and Wilson (2019)), or determine whether stock prices have an important impact on monetary policy decisions (Cieslak and Vissing-Jørgensen (2020)).

3 For an overview of various methods in the field of text mining in relation to economic issues, see Gentzkow et al. (2019).

4 It would also be possible to analyse paragraphs instead of sentences. However, paragraphs could prove to be too comprehensive, especially if the topics to be analysed are more specific. Therefore, sentences are chosen as the unit of text, with each sentence being assigned one topic, much like the analysis of FOMC statements in Hansen and McMahon (2016).

5 See Blei et al. (2003).

6 A small and symmetrical value is selected for the parameters of both distributions, so that both the probability vectors over the topics for the respective sentences and the probability vectors over the words for the respective topics have many zeros. As a result, only a small number of topics are assigned to the individual sentences and the individual topics are dominated by only a few words.

7 See Hansen et al. (2018) for a brief discussion of methods for determining the number of topics. In their analysis of the transcripts of FOMC meetings, the authors likewise set the number of topics at 40. By contrast, procedures that optimise the goodness of fit are often said to select too many topics.

Frequency of selected words or groups of words in ECB press conferences*

The 10 most common words or groups of words		Other words or groups of words	
Word	Frequency	Word	Frequency
question	8,523	monetary policy	2,650
growth	5,194	interest rate	2,448
euro area	4,792	price stability	2,091
rate	4,340	euro	1,771
market	3,835	fiscal	1,129
inflation	3,743	exchange rate	832
time	3,459	currency	403
first	3,255	foreign exchange	62
ecb	3,181	purchasing power	44
govern council	3,076	carry trade	14
Total number of words and groups of words			527,266

* Period under review: 9 June 1998 to 12 March 2020. As the words were already reduced to their root form before the groups of words were formed, this is also reflected in the groups of words (e.g. "govern council" instead of "governing council").

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– All non-alphabetical "words", except common economic terms such as the money aggregates M1 to M3, are removed; the names of the respective presidents and vice-presidents are also excluded from the analysis. This seems sensible, as both numbers and these names are frequently mentioned without being of material relevance to the present analysis.

– Other words that occur very frequently but are scarcely of material relevance, such as "the", "and" or "they", are also removed. These make up around half of all the words in the text corpus and would thus dominate any statistical analysis of the text.

– The remaining words are reduced to their root form.[8]

– Groups of up to four words are formed by extracting particularly common word combinations such as "exchange rate" or "monetary policy" from the text.[9]

– Finally, words that only occur once in the entire text as well as some other words that are very frequent yet not materially significant[10] are excluded from the analysis. As the topics searched for are determined on the basis of individual sentences, sentences that have fewer than three words after these steps have been taken are also discarded.

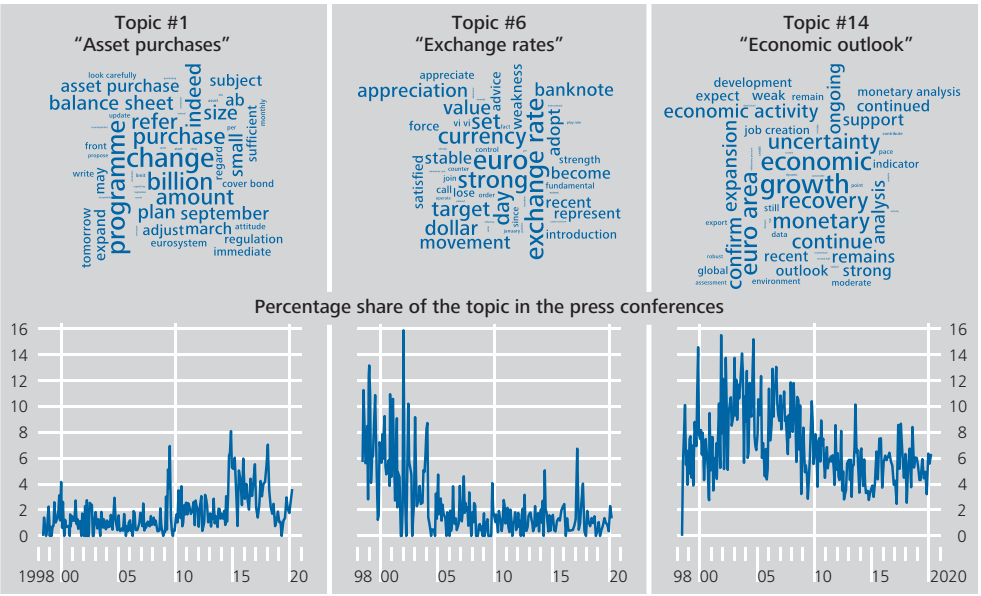
The text corpus is thus reduced from the aforementioned 1.4 million words to just under 530,000 words.

The adjacent table shows the frequency of selected words in ECB press conferences. Just looking at this table, it is apparent that, consistent with the ECB's mandate, issues relating to the euro exchange rate are not given a central role in communication. Although the word "euro" appears more than 1,700 times, it can be used in various contexts. Other words used in connection with the exchange rate appear much less frequently. This becomes particularly clear when comparing the frequency of these words with terms that do relate to the core topics of monetary policy communication, such as "interest rate" or "price stability". However, the most frequently used terms are usually less specific and can be used in relation to various topics.

The chart on p. 23 shows three selected topics from the LDA analysis, including their respective "word cloud" and the share that each topic represents in all sentences con-

8 For example, the words "took" and "taken" are both reduced to their root form "take". This is done using the WordNet lexical database (https://wordnet.princeton.edu).
9 See Mikolov et al. (2013). The groups of words formed in this way are subsequently treated as words in their own right.
10 This word list consists of "say", "would", "also", "see", "think", "could" and "however".

Selected topics from the LDA analysis and their share in press conferences following monetary policy meetings of the ECB Governing Council*



* The word clouds show the most significant words for each topic, with the size of each word increasing with its importance. The topics shown can be interpreted as asset purchases (topic #1), exchange rates (topic #6) and economic outlook (topic #14). The share of the respective topics in the press conferences during the period 9 June 1998 to 12 March 2020 is determined by the share of sentences in the press conferences that are assigned to each topic. Each sentence is assigned to the one topic that is most likely according to latent Dirichlet allocation (LDA) analysis.

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tained in ECB press conferences over time. Word clouds visualise the words that constitute a topic. The larger the word appears in the cloud, the more important it is for the topic.[11] Topic #6, for example, is dominated by exchange rate-related terms such as "euro", "exchange rate", "currency" or "dollar". It can therefore be labelled as an "exchange rate topic". The accompanying chart shows that in the first few years after the introduction of the euro, the exchange rate topic played a somewhat greater role in communication. One press conference of note here is that of 3 January 2002, for example. Not only was this the first monetary policy meeting following the introduction of euro banknotes, it also took place during a period of pronounced euro weakness. As a result, there was speculation about possible ECB intervention in the foreign exchange markets in favour of the euro. It is therefore not surprising that the first four questions asked by journalists following the introductory remarks of the then ECB President Wim Duisenberg related to the euro exchange rate. With few exceptions, however, the exchange rate topic played only a small part in ECB communication in subsequent years. One of these exceptions was 9 March 2017. In response to criticism by the new US administration of the current account surpluses of some euro area countries, Mario Draghi, the ECB President at the time, emphasised – following questions from journalists – that the euro was not undervalued compared with the long-term average. These two examples suggest that the exchange rate topic may have taken on a more prominent role mainly as a result of questions from journalists.

In order to assess the quality of the LDA analysis, it is also worth taking a brief look at other topics. Topic #1 in the chart deals

11 How important a word is for a topic is determined by the entry in the respective probability vector for the topic over all words in the text corpus.

with the Eurosystem's asset purchase programmes. Large fluctuations in the importance of this topic in ECB communication first appear in mid-2009, when the first covered bond purchase programme (CBPP) was announced and implemented, with even greater volatility seen later as of October 2014 with the announcement of the asset-backed security purchase programme (ABSPP) and the now third CBPP.[12] Topic #14, by contrast, focuses on the economic outlook, which is generally part of the introductory remarks. This topic therefore plays a particularly important role in all press conferences.

The text-mining approach used here therefore gives the following answer to the question asked at the beginning of this box on the role of the euro exchange rate in Eurosystem communication. In line with the widespread notion that the exchange rates of large, advanced economies should be determined by market forces, exchange rates play a fairly minor role in the ECB's communication. Any monetary policy impulses on the exchange rate resulting from Eurosystem communication are therefore very likely not the primary objective of this communication.

12 It should be noted here that the LDA analysis determines the topics without any economics-based specifications and solely on a statistical basis ("unsupervised learning"). Topic #1 can therefore be interpreted as in the text, but it also takes up other issues, albeit to a lesser extent. It is therefore not surprising that the share of topic #1 is greater than zero even in the press conferences held before the first CBPP was announced. Isolated keywords on asset purchase programmes are also found in word clouds not listed here, for example in a topic with a strong link to forward guidance. However, the exchange rate topic, which is the main focus here, is fairly clearly distinguished from the other topics by the LDA analysis.

Exchange rate matters play a secondary role in the communication of the ECB Governing Council

In today's system of flexible exchange rates in many medium-sized and large advanced economies, there is no longer this conflict of aims between the free movement of capital and scope for monetary policy decision-making,[5] as balance of payments imbalances tend to be reduced by adjustments to the exchange rate. Net capital outflows would then result in a depreciation of the domestic currency and thus tend to lead to an improvement in the current account balance that would offset the financial account deficit. Owing to the changeover to systems of flexible exchange rates, exchange rates are nowadays no longer a target variable for the Eurosystem and most other central banks of large advanced economies,[6] which is why interventions in the foreign exchange market are undertaken by them only in exceptional cases.[7]

This is also reflected in the Eurosystem's communication of monetary policy. A breakdown of all the press conferences following monetary policy meetings of the Governing Council of the ECB employing state-of-the-art text mining techniques produces a clear-cut picture (see the box on pp. 21ff.) Apart from in the initial phase following the introduction of the euro, exchange rate matters have played no more than a secondary role in this important means

5 The conflict of aims between the free flow of capital, fixed exchange rates, and scope for independent monetary decision-making is also known as the "impossible trinity". Only two of these objectives can be achieved at the same time. Recently, however, there has been discussion about whether this trilemma has not changed into a dilemma; see Rey (2015) and the literature building on it.
6 The exchange rate does, however, affect the general domestic price level through its impact on import prices and may thus – at least in the event of major fluctuations – also be of monetary policy relevance when pursuing an inflation target.
7 The most recent event of this kind for the Eurosystem was a coordinated foreign exchange market intervention in March 2011, when the Bank of Japan, the Bank of Canada, the Federal Reserve, the Bank of England as well as the ECB intervened jointly to counter upward pressure on the Japanese yen. The yen began to rise in value in the aftermath of a devastating earthquake in Japan, prompting a response that included repatriation of Japanese external assets and increased demand for yen from insurers.

of communication for the Eurosystem. This is indicated firstly by a straightforward breakdown of how frequently certain words are used in the press conferences and is backed up by a more in-depth statistical analysis. Matters concerning exchange rates are brought to the fore, at most, in exceptional cases.

Uncovered interest parity …

Monetary policy nevertheless still plays a crucial role in determining exchange rates. One key mechanism for this in economic theory is uncovered interest parity (UIP). This theory states that the expected return on a secure investment in domestic currency must be same as that on an equivalent secure investment in foreign currency.[8] If domestic interest rates are lower than those on a comparable investment abroad, say, UIP requires that the investor expects an appreciation of the domestic currency over time which balances out the expected return on both investments. Otherwise, the expected higher return externally should prompt increased investment in foreign bonds, leading, along with other effects, to their prices rising and their interest rates falling until uncovered interest parity had been restored. According to this theory, these mechanisms ensure that uncovered interest parity is maintained.[9]

… as a key component of monetary models for determining exchange rates

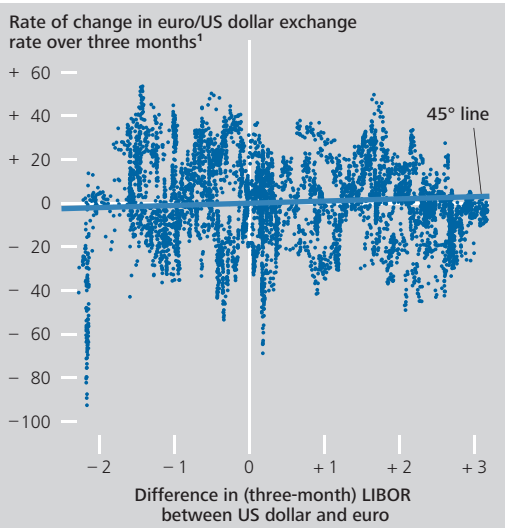
Uncovered interest parity is also a key component of many theoretical models for determining the exchange rate, as it is in the class of monetary models.[10] These make the simplifying assumption that government bonds of different countries differ, at most, in terms of their interest rates, which – under the additional assumption of rational expectations among market agents – already implies uncovered interest parity. A further major component of such models is purchasing power parity theory. In its simplest form (assuming fully flexible goods prices), this theory states that, after conversion into a single currency, an equivalent basket of goods in two countries must have the same price.[11]

"Overshooting" exchange rates

In the most widely used version of the monetary model, it is additionally assumed that goods prices adjust only gradually to market conditions. In this case, purchasing power parity theory holds only in the long term. An increase in the nominal money supply then also leads, at least temporarily, to an increase in the real money supply, as prices in the goods market are raised only with a time lag. If the additional funds are invested, say, in fixed interest securities, the nominal interest rate falls, leading to rising money demand which brings the money

Uncovered interest parity between the United States and the euro area*

Annualised %, daily data, 4 Jan. 1999 to 17 Aug. 2020



Sources: Refinitiv and ECB. * A single dot is derived from the difference between the US dollar-denominated and euro-denominated three-month London Interbank Offered Rate (LIBOR) on a given trading day and the rate of change in the euro/US dollar exchange rate over the next three months. When uncovered interest parity holds, the dots should be near the indicated 45° line, which appears very flat owing to the different scales of the axes. Deviations from this should be randomly distributed. **1** A positive value indicates an appreciation of the euro against the US dollar.

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8 "Equivalent" is to be construed here as both investments being risk-free, having the same maturity with no differences in potential transaction costs. This definition is a comparatively good fit in general for government bonds, particularly those of industrial nations like the United States and Germany.

9 More on the concept of interest parity (both covered and uncovered) may be found in Deutsche Bundesbank (2005).

10 Monetary models gained great popularity in the late 1970s and the 1980s after the end of the Bretton Woods system and the changeover to flexible exchange rate systems in many countries. Frenkel (1976) is regarded as pioneering the model with flexible prices and Dornbusch (1976) as the pioneer of the model with rigid prices.

11 For a more in-depth analysis of purchasing power parity theory and its use for assessing price competitiveness, see Deutsche Bundesbank (2004).

market into equilibrium again. In this environment, there are two factors at once which act to bring about a depreciation: the foreseeable price increase via purchasing power parity theory and the lower interest rates through uncovered interest parity. This means that, in this model framework, monetary expansion results directly in a disproportionate depreciation of the domestic currency. By virtue of the accompanying decline in the real money supply, the ensuing successive upward adjustment of the general price level also leads to the interest rate level returning to normal again. Because of this, what remains in the end is a depreciation of the domestic currency proportionate to the monetary expansion. This phenomenon in the model developed by Dornbusch is known as "overshooting the exchange rate".

Hardly any indication that UIP applies to euro/US dollar exchange rate

While the monetary approach yields simple and readily comprehensible mechanisms for the response of exchange rates to monetary policy impulses and it is repeatedly possible to observe the "overshooting" of exchange rates, empirical studies find very little evidence for the validity of one essential model component: uncovered interest parity.[12] This becomes immediately apparent when comparing the interest rate differential of comparable investments in the euro area and the United States with developments in the euro/US dollar exchange rate. If, for example, the interest rate on a three-month euro-denominated debt security is 1 percentage point above that on an equivalent security denominated in US dollar, UIP requires an expected, annualised 1% depreciation of the euro against the US dollar. In reality, though, the actual annualised depreciation of the euro follows this rules only in exceptional cases. Rather, it is possible to observe a very wide dispersion of exchange rate changes. In fact, contrary to the prediction of UPI, there are often cases where the euro even appreciates against the US dollar in the above case. Among the reasons for such scant evidence for UIP could be risk and liquidity premia for currencies, departures from rational expectations among market agents, the "peso problem",[13] as well as shortcomings in the economic approaches used.[14]

Reasons for departure from UIP

More recent models building on microfoundations and explanatory approaches for empirical findings

More recent approaches provide the model assumptions with a microfoundation. Consideration of firms' and consumers' intertemporal decision-making problems permits a dynamic analysis. Goods prices that adjust only gradually, as in the Dornbusch model, are captured here through a combination of monopolistic competition and limited power to set prices.[15] Refinements of these dynamic general equilibrium models of open economies also attempt to incorporate empirical evidence regarding the model assumptions. Thus, departures from purchasing power parity can be taken into account through introducing non-tradeable goods, for example, as well as through firms that set their prices on the (external) sales market (pricing-to-market), or through consumers having a preference for domestic goods.[16] Among the responses to a violation of UIP are the introduction of noise traders[17] or a time-varying currency risk premium.[18] The decoupling of

12 See Hansen and Hodrick (1980) and Fama (1984) for early influential studies in this direction. In the case of the second major component of the model, purchasing power parity theory, the results are more multifaceted. See Deutsche Bundesbank (2004) as well as Rogoff (1996) where this point was already brought up.
13 The peso problem describes a situation in the foreign exchange market where investors price in an extreme event with a small probability. Owing to the rarity of such events, empirical studies lack the relevant observations, leading to a biasing of the results. The name comes from a situation in the 1970s when the Mexican peso was pegged to the US dollar, but investors suspected that Mexico's central bank might not be able to maintain the peg on a permanent basis. Accordingly, despite the fixed exchange rate, there was a persistently positive interest rate differential between Mexican and US bonds. Following the end of the Bretton Woods system, a depreciation of the Mexican peso against the US dollar did indeed occur in 1976.
14 See Engel (2014) for an overview of the state of more recent research on interest parity.
15 Obstfeld and Rogoff (1995) are regarded as the pioneers of this new open economy macroeconomics (NOEM) model framework.
16 Both the existence of non-tradeable goods (see Obstfeld and Rogoff (1995)) and pricing-to-market (see Betts and Devereux (2000)) or home bias (see Warnock (2003)) can cause an "overshooting" of the exchange rate as in the Dornbusch model.
17 See Devereux and Engel (2002). Conditional forecasts of future exchange rates by noise traders are biased, which can lead to a departure from the assumption of rational expectations.
18 See Obstfeld and Rogoff (2003).

exchange rates and economic fundamentals – frequently observed empirically – can be better explained in this way. These refinements provide important insights into the way open economies function; the fundamental qualitative response of exchange rates to monetary policy impulses, however, resembles that of the monetary models. For example, there is indeed empirical evidence for an "overshooting "of the exchange rate, as was already predicted by the monetary model with rigid prices.

Empirical evidence for "overshooting" exchange rates greater

Indicators of the importance of monetary policy for euro exchange rate developments

Volatility on days of ECB Governing Council meetings an indicator in general …

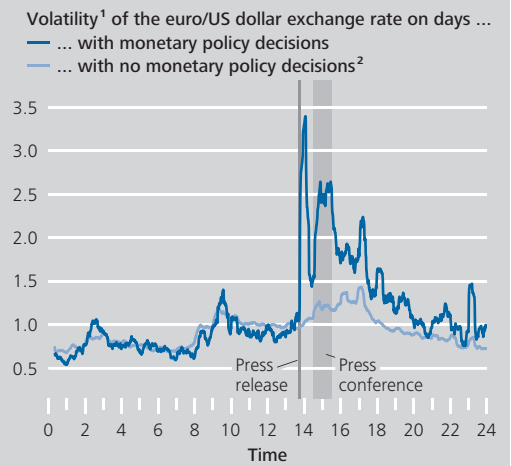
One way to gain an initial descriptive impression of the effects of monetary policy on exchange rates is to look at the development and fluctuation band of euro exchange rates within very short periods of time on days when the ECB Governing Council's monetary policy meetings take place. This shows a spike in such volatility calculated for the euro/US dollar exchange rate at 13:45 Central European Time (CET), which is when the press release is published. A second increase in volatility occurs during the subsequent press conference beginning at 14:30 CET. This pattern contrasts with days on which no monetary policy meeting takes place, when similar surges in volatility are not observed. This suggests that monetary policy communication plays a major role in foreign exchange markets.

… and based on examples

In this context, it is also unsurprising that several of the largest daily changes in the nominal effective exchange rate of the euro are linked to monetary policy announcements. Amongst other examples, these include 22 January 2015, when the ECB Governing Council's decision on the first major asset purchase programme (APP) triggered one of the largest ever depreciations of the euro. A similar situation was observed after the monetary policy meeting on 22 October 2015, after which the euro also experienced a particularly steep single-day loss.

Intraday volatility of the euro/US dollar exchange rate on days of the ECB Governing Council's monetary policy decisions*

Minute data



Sources: Refinitiv and Bundesbank calculations. * Scheduled meetings of the ECB Governing Council between 25 July 2019 and 10 September 2020. **1** Calculated using the standard deviation of minute-by-minute changes in the euro/US dollar exchange rate in rolling 20-minute windows. The average standard deviation across all observations is normalised to 1, meaning that values higher than 1 denote above average volatility. **2** Days within the specified time window on which neither the ECB Governing Council nor the Federal Open Market Committee made any monetary policy decisions.

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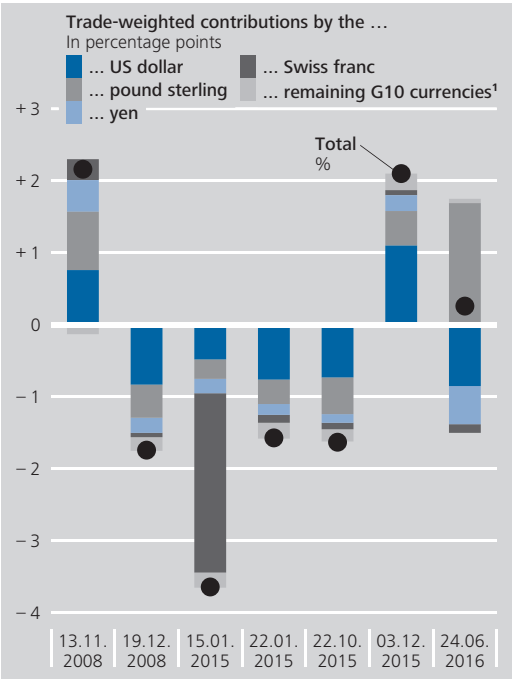
Owing to low inflationary pressures, the ECB Governing Council at that time announced a review of the monetary policy stance, which market agents saw as a signal for an expansion of the asset purchase programme. At the next ECB Governing Council meeting on 3 December 2015, the interest rate on the deposit facility was lowered by 10 basis points and the duration of the asset purchase programme was extended, though the monthly purchase volume remained unchanged. Despite what were, in fact, expansionary measures, the euro effective exchange rate then experienced one of its most marked single-day appreciations. This shows the crucial importance of expectation formation among financial market players for the impact of monetary policy announcements on foreign exchange markets.

Sharp movements in the euro exchange rate can be caused, moreover, by direct intervention in the foreign exchange market, or by the lack thereof. On 15 January 2015, for example, the

Selected effective daily gains and losses by the euro against the G10 currencies



Sources: Bloomberg (exchange rate fixing: 23:00 Central European Time) and ECB. **1** Australian dollar, Canadian dollar, New Zealand dollar, Norwegian krone and Swedish krona.

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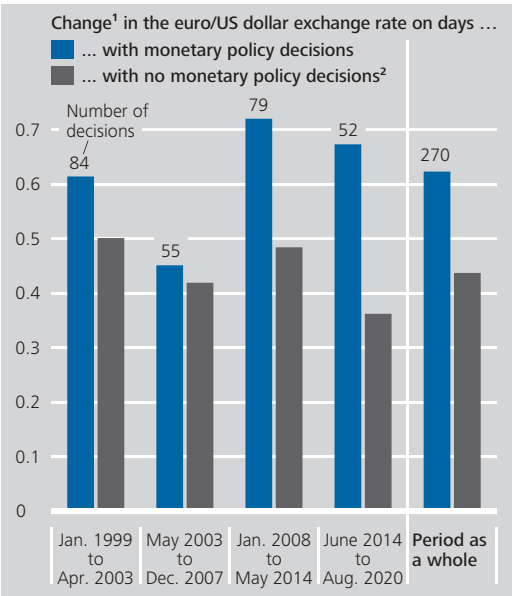
Daily changes in the euro/US dollar exchange rate on days of the ECB Governing Council's monetary policy decisions

%



Source: Bloomberg (exchange rate fixing: 23:00 Central European Time). **1** Average absolute daily changes. **2** Days on which neither the ECB Governing Council nor the Federal Open Market Committee made any monetary policy decisions.

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euro depreciated by almost 19% against the Swiss franc[19] when the Swiss National Bank discontinued the minimum exchange rate against the euro. As Switzerland is one of the euro area's most important trading partners, this measure had tangible consequences far beyond the bilateral euro/franc exchange rate.

Other factors also significant

However, this is not to say that the exchange rate developments of the euro are determined solely by central bank decisions. In addition to monetary policy, other events can also cause major shifts in foreign exchange markets. For example, the UK referendum on 23 June 2016 on a withdrawal from the EU led, amongst other things, to the euro appreciating by 6.2% against the pound sterling on the following day. At the same time, the euro depreciated, in some cases significantly, against currencies which tend to benefit from increased risk aversion amongst investors. During that day, the euro was 6.0% lower against the yen, for instance. Furthermore, several of the euro's strongest same-day movements occurred in the period when tensions were highest during the global financial crisis and are not necessarily directly related to monetary policy events.

Impact of euro area monetary policy on the euro exchange rate …

Based on this simple descriptive analysis, it is also possible to examine the extent to which the impact of monetary policy on the euro exchange rate, as measured in this way, may have changed over the euro's 20-year history. To do this, euro area monetary policy can be divided into four time periods:[20]

– the Eurosystem's beginnings until the first major adjustment of the monetary policy strategy (January 1999 to April 2003);

19 According to Bloomberg fixing at 23:00 CET.
20 This breakdown is more or less the same as that used by Vítor Constâncio, former Vice-President of the ECB, in his speech "Past and future of the European Central Bank monetary policy" at the conference "Central Banks in Historical Perspective: What Changed After the Financial Crisis?", held on 4 May 2018 in Valletta, Malta.

– the subsequent period until the onset of the financial crisis (May 2003 to December 2007);

– the outbreak of the global financial crisis plus the euro area debt crisis and their repercussions (January 2008 to May 2014);

– the low interest rate period and the launch of asset purchase programmes (from June 2014).

… has grown discernibly over time

To gain an initial overview of potential differences in the transmission of monetary policy to exchange rates across the aforementioned periods, it is worth looking at the average absolute daily changes in the euro/US dollar exchange rate. Generally, in each of these periods it can be seen that the daily changes in the euro/US dollar exchange rate were, on average, greater on days when monetary policy meetings of the ECB Governing Council were held than on other days. Moreover, it is possible to identify a change in this discrepancy over time as well. In the post-financial crisis period, in particular, exchange rate movements on days of monetary policy decisions become much more pronounced than movements on other days. During the most recent phase of exceptionally low interest rates, the discrepancy is becoming even greater. In fact, exchange rate fluctuations on days when the Governing Council makes monetary policy decisions are now, on average, almost as high as during the financial and debt crisis. On the other days, by contrast, they are smaller than ever before, on average. However, it is not possible to clearly conclude from this that the impact of Eurosystem monetary policy on exchange rates has increased over time.

However, the longer intervals between monetary policy meetings of the ECB Governing Council should be considered …

One factor that could put the above statement into perspective is the greater frequency of monetary policy meetings of the ECB Governing Council prior to the financial crisis in the euro area than since then. In the first three years after monetary union was established, they took place every two weeks, before a switch was made to a monthly cycle. The current six-week cycle was only introduced in 2015. As a result, individual decision-making days were probably less important in the early phase of the Eurosystem. It is therefore unsurprising that exchange rate movements on days of monetary policy decisions during this period are only marginally larger than on the other days. In the period following the interest rate cut in June 2003, in particular, no further interest rate adjustment was made over the next 29 monetary policy meetings. During this phase, then, monetary policy news from the euro area was presumably less significant for the development of the euro/US dollar exchange rate.[21]

… as should the strong monetary policy response during and after the financial crisis …

With the onset of the financial crisis, monetary policy once again took on greater significance for the exchange rate. In response to the lack of inflationary pressures associated with the economic downturn, the main refinancing rate was gradually lowered from 4.25% to 1% over a period of less than one year. Although the rate was raised again slightly two years later, the euro area debt crisis ultimately led to greater monetary policy accommodation, as a result of which the main refinancing rate was lowered to 0% by 2016. Against this background, it comes as no surprise that exchange rate movements on days of monetary policy decisions during this period were more pronounced than in the first decade after the launch of the euro.

… as well as possibly waning impulses from other factors

In the last phase, the expansion of the monetary policy toolkit to include non-standard measures, such as forward guidance and asset purchase programmes, also increased the com-

21 By contrast, this period probably saw stronger monetary policy impulses for the bilateral exchange rate emanating from the United States. A contractionary monetary policy cycle had already been set in motion there in mid-2004, with a gradual increase in monetary policy rates. However, the daily data used for this article make it difficult to directly compare the exchange rate effects on days of monetary policy meetings held by the two central banks. The Bloomberg fixing at 23:00 CET may not include the full effect of the decisions made by the Federal Open Market Committee, which are published and explained from 20:00.

plexity of monetary policy announcements. This phase of the Eurosystem's monetary policy is noteworthy for the strength that exchange rate movements continue to show on days of monetary policy decisions and the significant decrease in volatility on the other days.[22] There could be several reasons for the latter phenomenon. The period from mid-2014 to the end of 2019 was characterised by comparatively high economic growth and low inflation, for instance, which could have helped keep volatility at a generally low level in foreign exchange markets.

To sum up, there is much to suggest that monetary policy impulses play an important role, that perhaps varies over time, in exchange rate movements. However, in order to ultimately confirm this assumption and quantify this impact, an approach that can also capture causalities is needed.

Results of econometric approaches to determining the causal effect of monetary policy impulses on the exchange rate

Isolating the monetary policy impulse is a particular challenge, …

Early empirical studies on flexible exchange rates mainly focused on examining the assumptions underpinning the monetary model, particularly uncovered interest parity and purchasing power parity theory. By contrast, the more recent empirical literature increasingly addresses the question of the direct causal effect of monetary policy impulses on the exchange rate. One of the key difficulties here is determining the monetary policy impulse. Specifically, it is a matter of carefully disentangling a monetary policy impulse and its causal effects on exchange rates from the influences of other factors ("identifying" the monetary policy impulse). One challenging aspect is that monetary policy does not act of its own accord, but responds, above all, to economic developments.

… for example, in the case of a COVID-19-induced slump in demand

A slump in aggregate demand, for example, as was triggered by coronavirus,[23] tends to have price-dampening effects. Central banks have responded to this by cutting interest rates and expanding asset purchase programmes, to name two examples. These measures have to be regarded at least in large part as a response to market developments, otherwise the effect ascribed to monetary policy impulses would be inaccurate. In other words, instead of attributing the decline in inflation to the weak demand, it could be wrongly concluded that expansionary monetary policy leads to falling inflationary pressures.

Event studies

An event study …

One way of roughly quantifying the monetary policy impulse is to incorporate the aforementioned very narrow time windows surrounding monetary policy announcements into econometric estimates. In these event studies, the monetary impulse is usually measured using a short-term market interest rate (often an overnight index swap rate[24]). Assuming that absolutely no other relevant information was published in the specified period, the change in the interest rate measured in that period can be attributed solely to the monetary policy announcement. Assuming further that all previously published information has already been fully processed in financial markets, the change in the interest rate can be attributed entirely to a departure from the expectations of financial market agents, meaning that it reflects a mon-

22 Euro exchange rate volatility reached its lowest point in 2019. Against the G10 currencies, for example, this period exhibits the lowest average absolute daily changes in the nominal effective exchange rate of the euro since its launch. Implied volatilities – a measure of volatility derived from options – also reached historical lows in 2019 for key bilateral euro exchange rates.

23 The spread of coronavirus has undoubtedly had a negative impact not just on aggregate demand but also on aggregate supply. On balance, however, the dampening effect on demand prevailed – at least in the short term – as far as price pressures are concerned.

24 These are interest rate swaps whose variable interest rate depends on the average overnight interest rate in the interbank market (for the euro area, this is the EONIA).

etary policy impulse. As a final step, a simple regression can be used, for example, to determine the quantitative effect of the monetary policy impulse on the exchange rate.

… shows a significant impact of monetary policy impulses on the euro, which has in fact grown further over time

An event study such as this on the impact of the ECB's monetary policy announcements on the exchange rate of the euro against the US dollar, yen and pound sterling finds significant effects that are consistent with the theory (see p. 32). Thus, a contractionary monetary policy impulse is immediately followed by an appreciation of the euro against all three currencies. In quantitative terms, this effect is particularly pronounced when the monetary policy impulse works through medium and long-term interest rates. According to the estimate, an impulse which increases the yield on five-year German government bonds by 10 basis points causes the euro to appreciate by around 0.7% against the three currencies. In contrast to this, a monetary policy announcement of a comparable magnitude which works mainly through short-term interest rates only causes the euro to appreciate by just under 0.2% against the US dollar and the pound sterling. Its appreciation against the yen is even statistically insignificant in this scenario. The results of a time-varying estimate also confirm the above assumption that the impact of monetary policy impulses on the euro exchange rate has grown over time.

Quantitative and scientific context of the results

These results are relatively similar to those from comparable event studies for different currencies and the monetary policy of different central banks. According to those studies, a conventional, contractionary monetary policy impulse which increases short-term interest rates by 10 basis points leads directly to an appreciation of the domestic currency by between 0.1% and 0.3%.[25] Since, in reality, the movement in the short-term interest rates used for the analysis is barely more than roughly these 10 basis points in response to a typical policy rate adjustment of 25 basis points, the effect on the exchange rate appears to be small. However, it should be borne in mind, first, that expectations of monetary policy decisions have already been formed beforehand in the market, which have already influenced the exchange rate and market interest rates. The event study only identifies the effect of monetary policy decisions above and beyond these expectations. Second – as mentioned above – the present study shows, amongst other things, that measures targeting longer-term interest rate developments, such as asset purchases, have a stronger impact on the exchange rate.[26]

Vector autoregressive (VAR) models

VAR models with sign restrictions as an alternative

A second way of isolating a monetary policy impulse is to model the interdependencies between monetary policy and economic developments. Estimates of this kind are more complex than event studies and require theoretical considerations to be properly applied to the estimation procedure, but can do without minute-by-minute data. Unlike event studies, they also allow the dynamics of exchange rate responses to monetary policy shocks to be depicted. To this end, many studies employ vector autoregressive (VAR) models,[27] often using sign restrictions. The procedure can be illustrated using the above example of a COVID-19-induced decline in demand. According to the theory, the decline in demand leads to interest rate cuts in the money market, reduces economic output and has a disinflationary effect. The sign restrictions mentioned above can be used to calibrate the model such that the estimation only allows solutions that necessarily assume such a causal relationship. By contrast, an expansionary mon-

25 See, inter alia, Zettelmeyer (2004) for Australia, Canada and New Zealand; Kearns and Manners (2006) for the same countries and the United Kingdom; or Faust et al. (2007) for the United States.
26 Gürkaynak et al. (2005) pioneered such analyses; they use a "target shock" to cover short-term monetary policy rate adjustments and a "path shock" to cover the future path of monetary policy. Hausman and Wongswan (2011) predominantly attribute exchange rate movements following monetary policy impulses of the Federal Reserve System to such "path shocks".
27 VAR models assume that all of the observed variables are determined by their own past values as well as the past values of the other variables in the model.

An event study on the effects of monetary policy impulses on the euro's exchange rate

An event study can be used to quantify the effect of monetary policy impulses from the euro area on various euro exchange rates. It is also possible to examine whether this effect varies over time. This event study looks at the changes in euro exchange rates, equity prices and interest rates in a very narrow time period surrounding the ECB's monetary policy announcements. In this way, it attempts to separate the influence of monetary policy impulses on the euro's exchange rate from that of other factors. Specifically, all days of monetary policy meetings of the ECB Governing Council on which a press release was published and/or a press conference was held are taken into account. On these days, the median of the exchange rate quotations and interest rate quotations in the period of time between 13:25 and 13:35 and between 15:40 and 15:50 was determined. The change in exchange rates and interest rates during this period of time (i.e. the difference between the two quotations determined) therefore includes both the immediate responses to the press release published at 13:45 and to the roughly one-hour press conference commencing at 14:30.[1]

In traditional event studies, the measured change in interest rates would be interpreted as a simple measure of the monetary policy impulse. However, more modern analyses take into account the fact that monetary policy communication is multifaceted: for example, not only can it contain changes in the direct monetary policy stance, it can also deliver insights into the future monetary policy path and provide information on macroeconomic indicators. Especially in the latter case, economic effects can occur, inter alia, on the exchange rate, which are fundamentally different from those of purely monetary policy impulses.[2] If this is not taken into account in the analysis, its results may be distorted.[3]

In distinguishing between the three aspects of monetary policy communication mentioned above, the now established method of separating them by means of a principal component analysis is used.[4] Consider

$$X = F\Lambda + \eta,$$

where X is a $(T \times n)$ matrix containing the changes in n financial market variables surrounding T ECB monetary policy announcements. In particular, X here includes the changes in one-month, three-month and one-year OIS yields,[5] two-year, five-year, ten-year and 30-year yields on German government bonds and the Euro STOXX 50. Using the principal component analysis, X should now be reduced to $k=3$ unobserved factors, which describe the changes observed in financial market variables consolidated in X as accurately as possible.[6] F is a $(T \times k)$ matrix with the $k=3$ unobserved factors, Λ is a $(k \times n)$ matrix with the corresponding factor loadings, the coefficients of the factors, and η is an error term.

1 The data are taken from the Euro Area Monetary Policy Database of Altavilla et al. (2019).
2 See Jarociński and Karadi (2020). The effects of such "information shocks" and their influence on exchange rates are examined in more detail on pp. 42-45.
3 See Miranda-Agrippino and Ricco (2020).
4 See Gürkaynak et al. (2005).
5 Overnight index swaps (OIS) are interest rate swaps whose variable interest rate depends on the average overnight interest rate in the interbank market (for the euro area, this is the EONIA).
6 Swanson (2017) describes changes in financial market variables surrounding monetary policy decisions by the Federal Open Market Committee (FOMC), for example, also with three factors.

Results of the event study[o]

Impulse	EUR/USD	EUR/JPY	EUR/GBP	OIS 1M	DE 5Y
(1) Monetary policy (through short-term interest rates), β_1	0.19** (0.08)	0.08 (0.08)	0.17*** (0.06)	10.00*** (0.62)	2.65*** (0.49)
(2) Monetary policy (through medium and long-term interest rates), β_2	0.76*** (0.11)	0.77*** (0.11)	0.62*** (0.07)	0.68 (0.64)	10.00*** (0.52)
(3) Central bank information, β_3	– 0.10 (0.18)	0.26 (0.17)	– 0.07 (0.13)	4.09*** (0.81)	10.00*** (0.42)

o The table shows the estimated response (%) of the euro/US dollar exchange rate (EUR/USD), the euro/Japanese yen exchange rate (EUR/JPY) and the euro/pound sterling exchange rate (EUR/GBP), as well as the yields on one-month OIS (OIS 1M) and five-year German government bonds (DE 5Y) to the impulse shown in the first column. A positive coefficient indicates that the impulse leads to an appreciation of the euro. The impulses are normalised as follows: a monetary policy impulse on interest rates for short maturities increases the one-month OIS rate by 10 basis points (indicates an impulse of 2.8 standard deviations); a monetary policy impulse on the interest rates of longer-term government bonds and an impulse attributable to new central bank information each increase the yield on five-year German government bonds by 10 basis points (indicates an impulse of 3.1 and 4.9 standard deviations respectively). Standard errors of the estimated coefficients are shown in parentheses. * significant at the 10%, ** the 5% and *** the 1% level.

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The factors determined using the principal component analysis cannot initially be interpreted in a structural manner, i.e. in the sense of the three communication aspects. This results from a "factor rotation"

$$Z = FU,$$

with which, using the $(k \times k)$ matrix U from the original factors, F, new, structurally interpretable factors, Z, are calculated.[7] The matrix U was chosen such that the first two factors lead to an increase in yields and to price declines in the equity market, which is in line with the theoretical response to a contractionary monetary policy impulse. They differ in that the first impulse, known as a "target shock", has a greater impact on interest rates for short maturities (one-month and three-month yields), while the second impulse, a "path shock", has a greater impact on those for longer maturities (from one-year yields).[8] The first monetary policy impulse should, therefore, tend to reflect conventional monetary policy measures, while the second should also reflect, inter alia, unconventional measures such as forward guidance and asset purchases, which have a greater impact on medium to long-term interest rates. Finally, the third factor is intended to reflect the disclosure of central bank information, which, in the event of surprisingly positive information, leads to both yield and equity price increases.

A measure for the two monetary policy impulses $z_{1,t}$ and $z_{2,t}$ as well as for the impulse attributable to new central bank information $z_{3,t}$ is then derived from the standardised factors in the relevant columns of the matrix Z. Finally, their influence on the euro's exchange rate can be estimated using the following regression equation:

$$y_t = \beta_0 + \sum_{i=1}^{k=3} \beta_i z_{i,t} + \varepsilon_t,$$

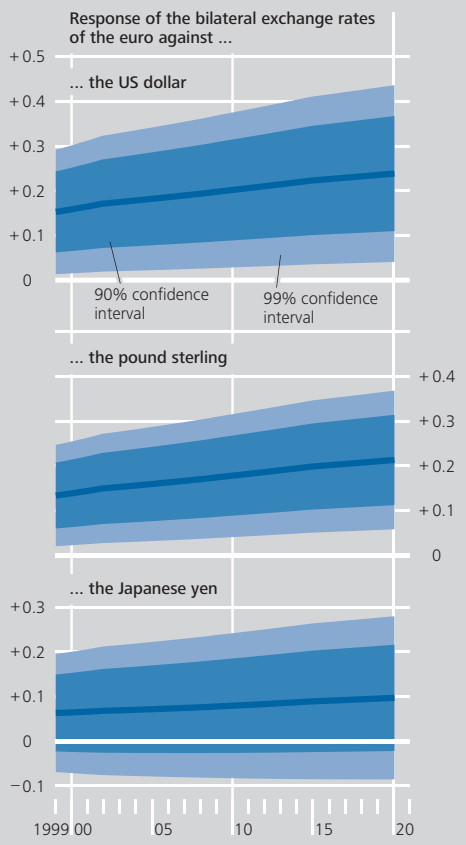
where y_t stands for the rate of change of the bilateral euro exchange rate against the

7 The factors of the matrix are orthogonal to each other and explain the observed data in the matrix X to the same degree as the factors of the matrix F previously.

8 The sign restrictions are implemented using the algorithm developed by Rubio-Ramírez et al. (2010). The appropriate factor rotation is then determined using the median target method developed by Fry and Pagan (2011).

Estimation of the monetary policy effect on euro exchange rates through short-term interest rates*

Response to monetary policy impulses (%)[1]



* Immediate response of euro exchange rates to monetary policy impulses over time. **1** Impulses each normalised such that they increase the one-month OIS yield by 10 basis points. A positive value indicates an appreciation of the euro against the respective currency.

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US dollar (or the Japanese yen or the pound sterling) within the above-mentioned period of just over two hours on days of monetary policy decisions.

The table on p. 33 shows the estimation results of the event study for the coefficients β_1 to β_3. It shows that monetary policy impulses have a statistically significant influence on the three exchange rates, but the quantitative effect depends on whether interest rates for short or for long maturities are more likely to be affected. According to the estimation, the latter impulses, in particular, have a significant influence on the euro's exchange rate, also from an economic perspective. For example, an impulse that increases the yield on five-year German government bonds by 10 basis points leads to an appreciation of the euro from 0.62% against the pound sterling to 0.77% against the Japanese yen.[9] By contrast, impulses attributable to new central bank information do not immediately have a significant effect on any of the three euro exchange rates. One reason for this could be that the impact of such information impulses in foreign exchange markets is more complex than purely monetary policy impulses and thus takes longer than the just over two hours considered here to be reflected in exchange rate movements.[10]

The event study presented here assumes thus far that the influence of monetary policy impulses does not change over time. However, particularly as a result of the convergence towards key interest rates of 0% or below and the use of unconventional monetary policy measures that this entails, the transmission of monetary policy to exchange rates might have changed. Whether this is actually the case or not can be tested using an estimation with time-varying coefficients, $\beta_{i,t}$:

$$y_t = \beta_{0,t} + \sum_{i=1}^{k=3} \beta_{i,t} z_{i,t} + \varepsilon_t$$

However, this equation cannot be estimated without further assumptions, as the number of coefficients exceeds the number of observations. One method of dealing

9 Such a stronger effect of monetary policy impulses which work mainly through interest rates with longer maturities is also found, for instance, by Hausman and Wongswan (2011).

10 In line with this, when using daily exchange rate changes, there is a significant effect of information impulses on various euro exchange rates. See Kerssenfischer (2019).

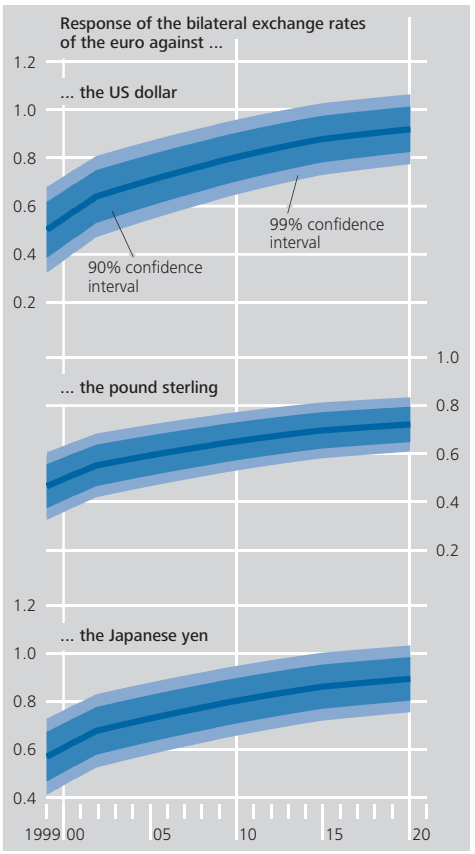
with this problem is a kernel estimation, where at any point in time $\tau = 1, ..., T$ all observations are assigned a weight. In this case, the kernel follows a normal distribution, meaning that the further the observation is from τ, the lower the weight assigned.[11]

The chart on p. 34 and the adjacent chart show the evolution of the estimated values for the coefficients of the two monetary policy shocks over time. Especially in the case of monetary policy impulses that have an impact on interest rates on government bonds with a medium and long-term residual maturity, the influence on euro exchange rates appears to have increased over time. At least since the use of explicit forward guidance from mid-2013 onwards and the launch of the public sector purchase programme (PSPP) in early 2015, unconventional monetary policy measures might have caused this development.[12] However, a corresponding trend can already be observed from the beginning of the observation period. Moreover, such a stronger response of euro exchange rates over time can likewise be seen, although to a lesser extent, in monetary policy measures which mainly have an impact on short maturities.

Another explanation could be the downward trend in interest rates observed worldwide. For example, interest rates might have been transmitted only to a lesser extent internationally since central banks' room for interest policy manoeuvre has tended to diminish over time. In this case, uncovered interest parity would predict larger exchange rate adjustments. Technological progress might also have led to information being priced into the market more quickly, for example, through increased algorithmic trading.[13] The response period selected here of just over two hours

Estimation of the monetary policy effect on euro exchange rates through medium and long-term interest rates*

Response to monetary policy impulses (%)[1]



* Immediate response of euro exchange rates to monetary policy impulses over time. **1** Impulses each normalised such that they increase the yield on five-year German government bonds by 10 basis points. A positive value indicates an appreciation of the euro against the respective currency.

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11 The actual weighting of the individual observations depends on the choice of bandwidth, h. The higher the bandwidth selected, the higher temporally more distant observations are weighted, meaning that, as h increases, there is convergence towards the linear case with coefficients which are constant over time. The choice of h here follows the optimisation method developed by Ang and Kristensen (2012). The same estimation method is also applied by Ferrari et al. (2017) to exchange rate changes following monetary policy announcements.

12 For a detailed discussion of the effect of the asset purchase programmes on the euro's exchange rate, see Deutsche Bundesbank (2017). This also shows that particularly the announcements regarding the purchase programme caused major movements in the foreign exchange markets.

13 See Ferrari et al. (2017).

for the first few years might then be too short to fully capture the effects of monetary policy measures. Ultimately, the frequency of monetary policy meetings of the ECB Governing Council could play a role: in the first three years after the launch of the euro, monetary policy decisions were taken every two weeks; between 2002 and 2014 they were taken every four weeks; and since 2015 they have only been taken every six weeks. It is conceivable that this decreasing frequency of meetings of the ECB Governing Council has increased the average strength of certain impulses over time. If euro exchange rates additionally respond disproportionately to larger shocks, this could also help explain the phenomenon of an increasing influence of monetary policy on euro exchange rates. However, such non-linearities are not the subject of this study, and a glance at the data fails to provide any definitive evidence of the possible increasing strength of monetary policy impulses.[14]

14 Not surprisingly, the strength of monetary policy impulses which have a stronger impact on interest rates with short maturities has declined, while the strength of monetary policy impulses which have a stronger impact on interest rates with medium and long-term maturities has increased.

etary policy impulse has a stimulating effect on the economy by lowering interest rates, thus raising the price level. These responses, too, can be imposed on the estimation using sign restrictions. Since the two impulses, falling demand and a monetary policy easing, are assumed to have different effects, they can be clearly distinguished from one another.

From mid-2014, weak euro largely due to monetary policy impulses

If, in addition to the monetary policy impulse, a VAR model then identifies other impulses, such as a real economic impulse, it is possible to calculate the extent to which these impulses have caused the historical development of the euro exchange rate, according to the model estimate. This kind of historical decomposition of the development of the euro/US dollar exchange rate suggests, amongst other things, that monetary policy is largely responsible for the euro's weakness from mid-2014 onwards (see the box on pp. 37 ff.). The euro/US dollar exchange rate was depressed not only by the expansion of asset purchases in the euro area, but also later by the Federal Reserve's gradual policy rate hike. The euro partially recovered in 2017, not least owing to the tapering of the Eurosystem's net asset purchases, but the US dollar was supported by the US economy, which had been booming up until the coronavirus crisis. Generally speaking, such historical decompositions are a useful analytical tool, precisely because they also make it possible to quantify the individual contributions of the impulses. Nevertheless, it should be noted that VAR models isolate just a limited number of such impulses,[28] meaning that they can only depict complex dynamics, for instance in the event of extreme events such as the coronavirus crisis, to a limited extent.

28 In principle, the number of impulses is unlimited. However, the calculation intensity for identification using sign restrictions increases exponentially, which means that, in practice, models will rarely include more than five different impulses.

Determinants of the cumulative change in the euro-US dollar exchange rate: a historical decomposition in a VAR model

When analysing the causes of movements in the euro-US dollar exchange rate, it should be borne in mind that the various determinants can affect the exchange rate not only immediately but also with a time lag. Information on the historical (lagged and non-lagged) determinants of the euro exchange rate is provided by an analytical procedure known as historical decomposition from a structural vector autoregressive (VAR) model. This procedure decomposes the euro-US dollar exchange rate movements into the contributions of the determinants identified in the model; the impulses they impart to the economy are termed "structural shocks" in this context. In order to calculate these shocks, such as the impulses generated by the Eurosystem's monetary policy over a given period of time, theory-based assumptions are made as to the direction in which they act on the economic variables observed in the VAR model over the same period (the shocks are "identified" by means of "sign restrictions"). The VAR model used here incorporates variables from two currency areas: the euro area and the United States.[1]

In mathematical terms, for a reduced-form VAR model with n variables, one of which is the euro-US dollar exchange rate, the following equation is to be estimated:

$$y_t = c + B_1 y_{t-1} + \ldots + B_p y_{t-p} + u_t,$$

where y_t is the $(n \times 1)$ vector of the endogenous variables, c is the $(n \times 1)$ vector of the constants, B_i is the $(n \times n)$ coefficients matrix of the endogenous variables lagged by $i = 1, \ldots, p$ periods and u_t is the $(n \times 1)$ vector of the error terms. As usual, u_t is normally distributed, with $E(u_t) = 0$ and $E(u_t u_t') = \sum$ assumed.

A special feature of this VAR model is that weekly financial market data are used as variables for the estimation instead of the monthly or quarterly macroeconomic data which are often used otherwise.[2] This lends the analysis a maximum of timeliness, which is of major interest, especially when looking at financial market variables such as the exchange rate. A total of five variables are incorporated into the model (and thus into vector y_t): the euro-US dollar rate, the Euro Stoxx 50 index, the S&P 500 index and the yields on ten-year Bunds and on ten-year US Treasuries. The model is estimated for the period since the introduction of the euro until mid-August 2020 using the least squares method and a maximum lag of $p = 5$ weeks, selected using the Akaike Information Criterion (AIC).

Although the coefficients $(c, B_1, \ldots, B_p)$ and the covariance matrix of the reduced-form VAR model, $\sum$, can be estimated without any problems, it is not possible to interpret the identified error terms, u_t, as structural shocks, as these error terms are correlated with one another. The VAR model is therefore converted into a structural form by imposing sign restrictions on the impulse-response functions, which allows an economic interpretation of the in-

1 The basic idea behind the model used here is to build on the approaches of Matheson and Stavrev (2014) as well as Farrant and Peersman (2006).
2 Not only are many types of macroeconomic data published only monthly or even quarterly, they are also often published only with a long time lag, which makes it difficult or virtually impossible to investigate current developments using these data.

Sign restrictions of the structural VAR model

Variable[1]	Contractionary monetary policy shock in the euro area	Positive macroeconomic shock in the euro area	Positive macroeconomic shock in the United States	Contractionary monetary policy shock in the United States	Residual shock
Euro-US dollar exchange rate[2]	+	+	–	–	–
Euro Stoxx 50	–	+			
Yield on ten-year Bunds	+	+	+	+	+
S&P 500			+	–	
Yield on ten-year US Treasuries			+	+	–

1 A + (–) indicates an immediate increase (decrease) in the value of the respective variable. **2** + indicates an appreciation of the euro against the US dollar.

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dividual shocks.[3] In the present VAR model, a total of four structural shocks and one residual shock are identified in this manner, the sign restrictions of which are given in the table above.

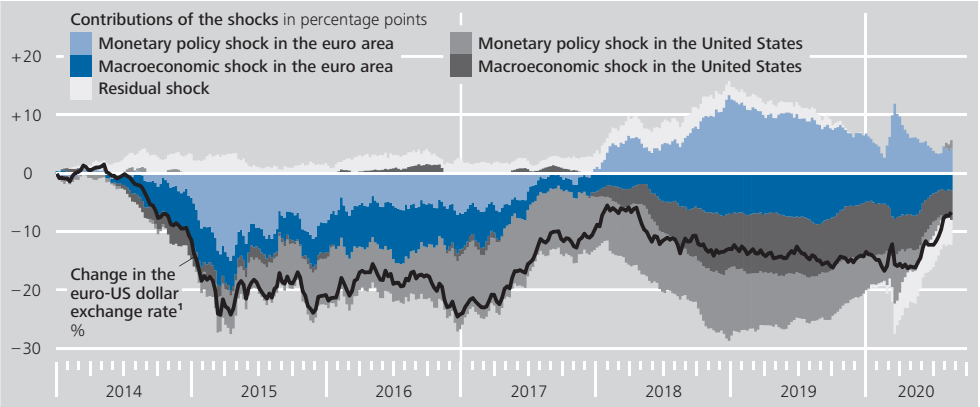
The model distinguishes between monetary policy shocks and other macroeconomic shocks, as well as between shocks originating in the euro area and those emanating from the United States. It is assumed that a contractionary monetary policy shock and a positive macroeconomic shock (e.g. the publication of surprisingly positive economic data) will both lead to a rise in domestic interest rates and thus to an appreciation of the domestic currency. However, the two shocks differ in terms of their impact on the stock market: a positive macroeconomic shock is assumed to increase the valuation of domestic equities, whereas the contractionary monetary policy shock will reduce the dividend discount value of equities through a deterioration in the economic outlook and a higher discount factor. In order to be able to additionally disentangle euro area shocks from US shocks, it is assumed that the United States, as the world's most important economy, plays a pivotal role in the global financial system inasmuch as changes in US interest rates are transmitted to euro area interest rates.[4] This means that both a positive macroeconomic US shock and a contractionary US monetary policy shock, each taken in isolation, will push up interest rates not only in the United States but also in Germany. Since it is assumed, however, that the interest rate hike in the United States will be passed through less than proportionately and that the increase will therefore remain larger there than in Europe, both shocks cause the euro to depreciate against the US dollar (see "uncovered interest parity"). Ultimately, a minimum number of sign restrictions are assigned to the residual shock in order to differentiate it clearly from the other shocks and thus not diminish its explanatory power.

The chart on p. 39 shows the historical decomposition of the euro-US dollar exchange rate. The black line indicates its cumulative percentage change since the end of 2013. The differently shaded areas reflect the respective contributions of the shocks identified in the model to the change in the euro-US dollar exchange rate. It can be seen that, from the end of 2013 – when the euro

3 The reader is referred to Chapter 10 of Kilian and Lütkepohl (2017) for a detailed and technical discussion of sign restrictions.
4 This is also consistent with the idea that US monetary policy is at the centre of the global financial cycle (see Rey (2015)).

Historical decomposition of the euro-US dollar exchange rate

Cumulative change since end-2013, weekly averages



1 An increase indicates an appreciation of the euro against the US dollar.

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was still trading at close to US$1.40 – up to the first quarter of 2015, the euro had lost nearly 25% of its value against the US dollar. The historical decomposition suggests that a large part of this was due to an accommodative monetary policy stance in the euro area. Important announcements and decisions on the Eurosystem's bond purchase programmes were made during this period, in particular including the adoption of the expanded asset purchase programme (APP). It is true that there was initially an easing of the downward pressure on the euro against the US dollar as the year progressed. From the end of 2015, however, the positive outlook for the US economy encouraged the Federal Reserve to raise the fed funds rate in increments again. Taken in isolation, this strengthened the US dollar. According to the analysis, the monetary policy stance on both sides of the Atlantic led, at the end of 2016, to the euro falling to its lowest level against the US dollar since 2002.

The euro subsequently recovered significantly, however, mainly supported by the gradual tapering of the net asset purchases by the Eurosystem. This perceived contractionary effect of monetary policy persisted into 2019. Nevertheless, from as early as the end of 2017, the upward tendency of the euro this originally triggered was already being thwarted by steady US economic growth during this period, along with other factors. This is reflected in an increasing importance of the US macroeconomic shock (see the chart above). Placing an additional strain on the euro was the somewhat gloomier economic outlook on the other side of the Atlantic, as evidenced by the intensifying effect of the macroeconomic shock from the euro area. On balance, this caused the euro to trend downward moderately but continuously up to end-2019.

The model also provides clues about the causes of current exchange rate developments during the coronavirus crisis. Since the euro area is more closely interconnected with China – the first country to be affected by the novel coronavirus – than the US economy is, the euro area economic outlook began to deteriorate as early as January 2020, putting downward pressure on the euro against the US dollar. Monetary policy impulses from the euro area were also weighing on the euro during this period. However, with the global spread of

the virus, this was increasingly counteracted by the similarly deteriorating outlook for growth in the United States. At the end of February, according to the estimation results, the contribution of euro area monetary policy area did a sudden about-face towards supporting the euro. This may have been due to market participants seeing the Eurosystem, with a main refinancing rate of 0% and a deposit rate of -0.5%, as having barely any room left for any further interest rate cuts compared with other central banks. However, beginning with the announcement of the pandemic emergency purchase programme (PEPP), upward pressure on the euro being applied by euro area monetary policy gradually subsided from the second half of March. By contrast, the US Federal Reserve had only just begun to cut its rates again following multiple policy rate hikes in the second half of the previous year. This gave the Federal Reserve the leeway it needed to lower the fed funds rate several times in response to the spread of the COVID-19 pandemic. On balance, US monetary policy was, at this stage, applying pressure on the euro to appreciate against the US dollar, unlike before the crisis. Toward the end of the observation horizon, both macroeconomic shocks also support the euro against the US dollar, presumably owing to differences between the two currency areas regarding the speed at which the pandemic spread and the associated revisions to the respective economic outlook.

It should be borne in mind, however, that such an analysis – as is usual in economics – rests on a large number of assumptions and should therefore be interpreted with caution. This is particularly true for the current year, as the COVID-19 pandemic ushered in developments, especially in the equity markets, which are difficult to model, and a model based solely on financial market variables cannot adequately represent the attendant complex dynamics of supply and demand shocks. Particularly in crisis situations, investors, irrespective of interest rate developments, temporarily shift funds to "safe haven" currencies such as the US dollar, which is something the present VAR model cannot adequately capture. On the whole, however, such historical decompositions from VAR models can be a useful avenue to understanding exchange rate movements.

Proxy VAR models

Combination of event studies with VAR models …

And finally, methodological refinements over the past few years now allow estimates in which monetary policy impulses are, like in event studies, isolated at very high frequency surrounding monetary policy announcements by altering variables, and a dynamic exchange rate response can nevertheless be determined using a VAR model.[29] Interestingly, first studies that apply this method confirm the theoretical idea that exchange rates "overshoot" almost immediately after monetary policy impulses.[30] It is worth highlighting this result as many studies with VAR models find only a lagged "overshooting" of exchange rates following monetary policy impulses.[31]

… allows dynamic analysis of impulses triggered by the announcement of central bank information

Although a very short-term definition of events that are relevant from a monetary policy perspective is used in an attempt to isolate a monetary policy impulse as exactly as possible, the question remains as to how successful this is in such event studies. This would be the case if the interest rate changes observed in the market during monetary policy announcements or shortly thereafter really are completely caused by monetary policy impulses in the stricter sense. This is not necessarily the case, however. Alongside the monetary policy decision, central banks regularly also communicate (explicitly or implicitly) additional information on their assessment of the economic situation and the outlook for the economy and for inflation.[32] If interest rates rise in the minutes following a monetary policy decision, this could equally be because, for instance, the central bank has communicated unexpectedly upbeat economic prospects. However, the effects of such information impulses are fundamentally different from those of genuine monetary policy impulses. Rather than depressing prices and economic output, the usual response to a contractionary monetary policy impulse, the rise in interest rates in the markets triggered by the brighter economic prospects is, in this case, actually associated with rising output and appreciating prices. The macroeconomic responses are therefore more comparable to those of a demand impulse.[33]

Positive information impulses triggered by ECB communication cause heterogeneous responses by the euro, …

Interest rate increases triggered by information impulses also have a different effect on exchange rates than pure monetary policy impulses – as demonstrated by a new Bundesbank study[34] (see pp. 42 ff.). If the ECB communication following one of its monetary policy meetings triggers a pure monetary policy impulse, this results in an "overshooting" of almost all examined bilateral euro exchange rates in line with the predictions of the Dornbusch model.[35] In the case of a positive information impulse, meanwhile, where the central bank communication improves the economic outlook, the response of euro exchange rates differs depending on the partner currency.

… where the euro depreciates against the currencies of commodity-exporting countries …

Despite the increase in interest rates at home, the euro depreciates in some instances, for example against the Australian dollar or the Norwegian krone. According to the results of the study, this has to do with the fact that the information impulse also has a considerable, positive impact on investors' global appetite for risk. Irrespective of interest rate developments, demand for speculative currencies, in particular, is high when markets experience rising risk

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29 In such an approach, the change in an interest rate at very high frequency surrounding monetary policy announcements is used as a proxy for the actual monetary policy impulse. The underlying idea behind these proxy VAR models, which are also termed VAR IV because of their similarity to an instrument variable approach, was developed by Stock and Watson (2012) and Mertens and Ravn (2013).
30 See Franz (2020) for an immediate "overshooting" following Eurosystem monetary policy impulses and Rüth (2020) for a comparable result for the United States.
31 See Eichenbaum and Evans (1995) and Scholl and Uhlig (2008), to name just two.
32 Romer and Romer (2000) already showed that market participants adjust their own forecasts in response to such communications.
33 See Jarociński and Karadi (2020).
34 See Franz (2020).
35 This is the case against the pound sterling, yen, Canadian dollar, Australian dollar, New Zealand dollar and the Norwegian krone. There is evidence for a lagged "overshooting" only against the US dollar. By contrast, the response of the euro exchange rate against the Swedish krona is statistically not significant.

The impact of central bank communication on the euro exchange rate

Analyses of high-frequency data surrounding monetary policy meetings often identify a co-movement of yields and equity prices. Theoretically, though, a contractionary monetary policy "shock" ought to drive yields higher, clouding the economic outlook and raising the discount factor. Both of these impacts imply that equity prices should fall and thus that equity prices and yields should move in opposite directions. The observed co-movement of yields and equity prices can, however, be explained by shocks triggered by new central bank information. These are primarily impulses which occur when financial market agents change their view of the general economic situation or of certain macroeconomic variables in response to communication from the central bank. Specifically, central bank communication on short and longer-term forecasts of macroeconomic variables could give rise to impulses of this kind.[1] Not only are these central bank information shocks, as they are known, a frequent occurrence following announcements by the ECB or the Federal Reserve;[2] they also have altogether different implications for the economy than those triggered by pure monetary policy shocks.[3]

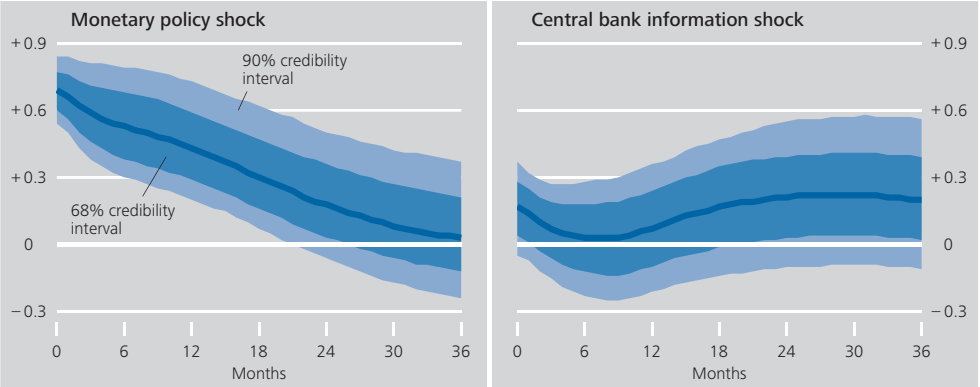
A recently published Bundesbank discussion paper investigates the impact of these central bank information shocks as well as the effect of pure monetary policy shocks on the euro exchange rate using a vector autoregressive (VAR) model.[4] This VAR model uses a total of eight variables as inputs. From the euro area, these are two-year yields on German government bonds, the EURO STOXX 50 index, industrial output, the consumer price index and a bank credit spread.[5] To capture the international dimension, foreign consumer prices as well as two-year yields and the euro nominal exchange rate are used.[6] The estimate is based on data from January 1999 to September 2018.[7] The reduced-form VAR model is estimated with Bayesian techniques.

In methodological terms, an approach known as a proxy VAR is used to disentangle, as far as possible, the two shocks observed in the model – the pure monetary policy shock and the central bank information shock – from other influences.[8] Short-term responses by yields on two-year German government bonds and the EURO STOXX 50 index are observed, as in an

1 Romer and Romer (2000) already tested for the existence of asymmetric information between the Federal Reserve and the public in inflation forecasting and demonstrated that monetary policy announcements provide signals for commercial forecasts. Expanding on this finding, Nakamura and Steinsson (2018) find evidence for an increase in professional forecasts of output growth following an unexpected rise in the real interest rate triggered by announcements by the Federal Open Market Committee; they label this a "Fed information effect."
2 See Cieslak and Schrimpf (2019).
3 See Jarociński and Karadi (2020).
4 See Franz (2020). A more formal presentation of the VAR model can be found on p. 37.
5 The bank credit spread is taken from Gilchrist and Mojon (2018) and denotes the difference in yields between bonds issued by commercial banks in the euro area and German government bonds. The spread aims to describe time-varying risk premia as a way of better approximating firms' and households' actual funding costs in the euro area. Gertler and Karadi (2015) support the inclusion of a variable of this kind since monetary policy measures can have a self-reinforcing effect on funding costs through these premia.
6 The VAR model is estimated, first, against 12 major trading partners such that the foreign variables are inputted in trade-weighted terms but, second, also bilaterally against the G10 currencies with the exception of Switzerland.
7 The maximum number of lags in the VAR model is set to 12 as is common for monthly data.
8 Since only two shocks are examined here, partial identification of the VAR model is sufficient. See Stock and Watson (2012) and Mertens and Ravn (2013) for an explanation of the workings of the proxy VAR method.

Impulse response functions of the euro effective exchange rate*

Percentage response to shocks[1]



* Relative to 12 trading partners. **1** Shocks normalised such that they increase the yield on German government bonds with a two-year residual maturity by 10 basis points. A positive value indicates an appreciation of the euro.

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event study.[9] This is done in a narrow window surrounding central bank announcements following monetary policy meetings of the ECB Governing Council.[10] These short-term yield and price responses are collated to form time series, which are then inputted into the model as proxies. It is thought that these responses capture the pure monetary policy shock and central bank information shock well if no further information that has a bearing on the aggregate economy was released during the period of the measured response and the two shocks largely cover the surprises from the ECB statement.[11] To ensure that this is the case, interest rate and price responses on days of monetary policy meetings of the ECB Governing Council were measured over a fairly short period of time, starting ten minutes before publication of the ECB press release at 13:45 CET and ending 20 minutes after the end of the press conference scheduled for 14:30 CET.

As a final step, the pure monetary policy shock then needs to be disentangled from the central bank information shock. This is done by additionally applying the sign restrictions mentioned above to the model. It is presumed that a contractionary monetary policy shock will raise domestic government bond yields and lower equity prices, while a positive central bank information shock will increase both yields and equity prices.[12]

The above chart shows how the effective exchange rate of the euro against 12 major trading partners responds to a positive central bank information shock and a contractionary monetary policy shock as impulse response functions. The shocks are normalised in terms of their magnitude such that the yield on German government bonds with a two-year residual maturity immediately responds with a 10 basis point increase. In the pure monetary policy shock, the rise in the interest rate leads to an economically and statistically significant appreciation of the effective exchange rate of the euro. The response is strongest at first (0.7%) and diminishes over time. This observation is consistent with the theoretical

9 See pp. 32 ff.
10 Data source: Kerssenfischer (2019).
11 Expressed in technical terms, valid restrictions can be obtained for identification if the proxies, much like an instrument variable estimation, are sufficiently correlated with the structural shocks of interest, but not with other possible structural shocks in the model.
12 These identifying sign restrictions are also used in Cieslak and Schrimpf (2019) and Jarociński and Karadi (2020).

Immediate response of the euro's bilateral exchange rate against various currencies[o]

%

Currency/variable	Monetary policy shock	Central bank information shock	Currency classification as per Hossfeld and MacDonald (2015)
US dollar	1.17*	0.98*	Carry trade funding/ safe haven
Pound sterling	1.03*	– 0.19	Not clear
Yen	0.48*	1.55*	Carry trade funding
Swedish krona	0.14	0.00	Speculative
Canadian dollar	1.38*	0.18	Speculative
Australian dollar	0.43*	– 0.33*	Speculative
Norwegian krone	0.53*	– 0.30*	Speculative
New Zealand dollar	0.70*	– 0.46*	Speculative
Effective	0.69*	0.17	Euro: hedge
VIX index	3.23*	– 8.00*	–

o The first and second columns show the immediate percentage response by the euro against the currencies indicated following a monetary policy shock or a central bank information shock which each increase the yield on German government bonds with a two-year residual maturity by 10 basis points. Besides the currencies shown in the table, the group of countries used to calculate the euro effective exchange rate includes Switzerland, the Czech Republic, Poland and Denmark. * denotes that the response shown is significant at the 10% level.

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framework of the Dornbusch model.[13] The central bank information shock, by contrast, does not trigger a statistically significant response by the effective exchange rate of the euro, despite the increase in the domestic interest rate.

To find out why the effective exchange rate of the euro responds differently to the two shocks, it is worth taking a look at bilateral euro exchange rates, specifically by estimating the VAR model for the euro exchange rate separately against each of the currencies listed in the above table,[14] which shows how the euro exchange rate immediately responded against each currency. As the table shows, the euro appreciated against all the currencies following a pure monetary policy shock, and did so in a statistically and economically significant manner, except against the Swedish krona. A central bank information shock, by contrast, elicited a very mixed response from the euro, depending on the partner currency concerned. As a case in point, the euro is estimated to appreciate very strongly against the yen, say, (by 1.6%), but lose value against other currencies, such as the New Zealand dollar (by 0.5% in this case).

What could be behind this distinctly mixed exchange rate response to central bank information shocks? Research on this matter suggests that different responses by the respective interest rate differential between the euro area and the country of the partner currency are not the main cause.[15] Things look more promising when the currencies under investigation are classified by the role they each play in the foreign exchange market (see the right-hand column of the table).[16] Analysis based on this classification approach identifies the low-yielding yen as a currency that is used to fund investment strategies such as currency carry trades. Investments in currencies of commodity-exporting countries such as Australia or Norway, on the other hand, have often carried higher rates of interest in the past, making them generally attractive to speculative investors. On the whole, it can be said that net capital flows into speculative currencies increase as global risk appetite picks up, subjecting them to up-

13 See Dornbusch (1976).
14 These are all the G10 currencies except the Swiss franc. Between September 2011 and January 2015, the Swiss National Bank pursued an exchange rate policy which prevented the Swiss franc from falling below a minimum exchange rate of CHF 1.20 per euro. As a result of this policy action, the Swiss franc was not free floating across a significant part of the period under observation. This complicated a comparison with the euro exchange rates of the other currencies, which is why the Swiss franc is disregarded here.
15 See Franz (2020).
16 Classification taken from Hossfeld and MacDonald (2015). This classification is derived from an estimation which attributes exchange rate movements to factors that go beyond interest rate and price developments.

ward pressure, whereas currencies used as safe havens, for hedging and to fund carry trades tend to depreciate as global risk appetite grows. If, then, it can be demonstrated that the risk appetite of global investors increases in response to a positive central bank information shock, this would make sense of the mixed response shown by various bilateral euro exchange rates to this particular type of shock.

The last row in the table shows the immediate response of the VIX index (which is a measure of the implied volatility of S&P 500 index options) to monetary policy and central bank information shocks. The VIX index is often used as an indicator of global risk appetite, with a decline signifying a rise in investors' risk appetite.[17] Following a positive central bank information shock, the estimate does indeed identify an immediate sharp rise in risk appetite, which ought to benefit speculative currencies. It is not surprising, then, that the euro depreciates against the very currencies that are classified as speculative or, at least, does not appreciate significantly against them. What is likely, though, is that the rise in risk appetite triggered by the positive central bank information shock will weigh on the exchange rates of currencies used to fund carry trades. And the analysis does indeed find that the euro gains in value against the US dollar and the yen, two currencies that belong to this category when classified according to this scheme. A pure monetary policy shock elicits a far weaker response by the VIX index than a central bank information shock, which is why the reduced risk appetite estimated in this case has no major bearing on euro exchange rates.

The analysis implies that central bank information shocks materialising concurrently with monetary policy shocks need to be borne in mind when investigating how monetary policy impulses impact on the euro's exchange rate. This is because the two shocks have substantially different effects on exchange rates. As a result, an estimation that disregards central bank information shocks might yield a distorted picture of the effect of monetary policy impulses on the euro's exchange rate.

17 The response by the VIX index shown in the table is derived from an estimation of the VAR model as described above, with the S&P 500 index and the VIX index serving as additional inputs.

appetite.[36] These frequently include the currencies of commodity-exporting countries, like the Australian dollar and the Norwegian krone mentioned above. It is consequently not surprising that the euro depreciates against these currencies in particular in response to a positive information impulse.

… and appreciates against currencies that are in demand when risk aversion is high

Conversely, a positive information impulse causes the euro to appreciate against other currencies, the US dollar or the yen, say. This appreciation appears to be strongest against currencies that tend to be in demand in times of high risk aversion. Unlike positive information impulses, purely contractionary monetary policy impulses do not lower risk aversion; if anything they increase it. As this effect appears to be relatively small, however, adjustments in investors' attitude to risk play no more than a secondary role in terms of pure monetary policy impulses.

Effect of non-standard monetary policy

Non-standard monetary policy and exchange rates: theoretical considerations …

Finally, in recent years, research has also focused on the question of how exchange rates respond to non-standard monetary policy measures, such as many central banks' asset purchase programmes or the use of forward guidance.[37] In particular, the following two theoretical transmission channels are being discussed. The portfolio rebalancing channel states that an expansion of central bank asset purchases in the secondary market will boost the prices of long-term bonds, thereby lowering their yields. Some investors will therefore restructure their own portfolio to include more foreign assets, amongst other things. The resulting capital outflows lead to a depreciation of the domestic currency. By contrast, the signalling channel acts by influencing investors' formation of expectations. The news of an expansion in asset purchases suggests a longer-term expansionary stance, which means that the expected level of future short-term interest rates will also adjust downwards. This will therefore again lead to a depreciation of the domestic currency.

… and empirical results

Empirical studies on non-standard monetary policy measures usually identify an economically and statistically significant effect on the exchange rate in the direction predicted by theory. The exchange rate effects identified in many studies are comparable in terms of their magnitude to those of conventional monetary policy.[38] However, some even consider the effect of non-standard measures to be greater.[39] This result may, however, be partly attributable to the fact that the sensitivity of exchange rates to monetary policy impulses has grown over time, as shown above.[40] Although most studies on non-standard monetary policy measures look at the Federal Reserve's monetary policy, there is certainly also evidence of a similar transmission to the exchange rate for the Eurosystem, especially in relation to the euro/US dollar exchange rate.[41] For other currency pairs, meanwhile, the effects appear to be fairly heterogeneous.[42] It can generally be concluded that exchange rates appear to be influenced by both long-term and short-term interest rate changes. It is therefore not surprising that non-standard monetary policy impulses are a significant factor in foreign exchange markets at times when short-term interest rates are 0%, given their impact on the longer end of the yield curve.

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36 See Hossfeld and MacDonald (2015) for a classification of G10 currencies.
37 A comprehensive analysis of Eurosystem bond purchases and their impact on the exchange rate of the euro can be found in Deutsche Bundesbank (2017).
38 See Rogers et al. (2014), Neely (2015) or Swanson (2017).
39 See Glick and Leduc (2018). This would also be compatible with the result that euro exchange rates are more sensitive to monetary policy impulses that work more through longer-term interest rates (see pp. 32 ff.).
40 See pp. 32 ff. and Ferrari et al. (2017).
41 See Deutsche Bundesbank (2017), Altavilla et al. (2015) or Dedola et al. (2020). The latter estimate, for instance, that an announcement on asset purchases which increases the Eurosystem's balance sheet by 20% as compared to the Federal Reserve's balance sheet, results in a 7% depreciation of the euro against the US dollar.
42 See Bluwstein and Canova (2016) or Fratzscher et al. (2016).

Conclusion

Monetary policy impulses have a significant impact on euro exchange rate developments. From a theoretical perspective alone, interest rate differentials are, alongside the price level, a key factor in determining the exchange rate. However, empirical evidence also suggests that the Eurosystem, for example, has a decisive influence on the exchange rate of the euro through its influence on the yield curve. Several analyses using very different methods evidence the large importance of monetary policy announcements for the exchange rate of the euro. It is consequently not surprising that some of the euro's largest single-day gains and losses are the result of just such monetary policy events. There are also signs that this influence has actually even intensified over time.

However, quantifying the effect of monetary policy impulses on euro exchange rates is proving complicated. For example, it is methodologically difficult to clearly identify a monetary policy impulse. In recent years, however, considerable progress has been made in quantifying monetary policy impulses and analysing their effects on exchange rates, mainly through the development of new statistical methods and the wider availability of high-frequency financial market data.

Another challenge is that monetary policy communication may also contain information that is relevant to financial markets but that does not directly relate to monetary policy but more to the economic outlook, say. Looking at the exchange rate of the euro, however, the effects of such information impulses differ significantly from those of pure monetary policy impulses and also vary considerably depending on which exchange rate pair is considered.

The results presented here suggest that a monetary policy impulse by the Eurosystem that raises the yield on five-year German government bonds by 10 basis points leads to an immediate appreciation of the euro against the US dollar, the yen and the pound sterling by around 0.7% in each case. By contrast, the estimated appreciation is much smaller on average if the monetary policy impulse works mainly through short-term interest rates. However, this result may have been partly caused by the general rise in the influence of monetary policy impulses on the euro. The analyses presented here also show that this impact has been considerable in recent years in terms of the euro/US dollar exchange rate, also compared with other macroeconomic factors. This suggests that monetary policy communication should not lose sight of the potential effects on the exchange rate of the euro.

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