The Eurosystem's bond purchases and the exchange rate of the euro

In January 2015, the Governing Council of the ECB announced an expanded asset purchase programme (APP) and thereafter twice extended its duration besides increasing the monthly volume of purchases. The aim of the programme is to bring inflation in the euro area back up to rates that are below, but close to, 2% over the medium term. Theoretical considerations suggest that there are a number of mechanisms through which asset purchases should be instrumental in achieving the desired effect. These mechanisms are aimed directly at investors' portfolio decisions and market players' monetary policy expectations; the relevant adjustments may also indirectly involve a depreciation of the euro.

Against this background, the present article is concerned with the impact of the Eurosystem's bond purchases on the euro's exchange rate. To this end, we first look at how the exchange rate responded on the dates on which the Governing Council of the ECB took its decisions on the asset purchase programme. In this context, the considerable depreciation of the euro on the day the APP was adopted is particularly striking; a larger daily fall in the euro's effective exchange rate had been recorded only once previously.

This is all the more notable considering that market expectations about such measures had already led to the euro depreciating in the preceding weeks. There are, however, numerous inherent difficulties in quantifying the effects that changes in expectations about the APP had on the euro's exchange rate. For example, a depreciation of the euro tends to reflect not only the quantitative easing of the Eurosystem, but also its standard policy measures as well as the gradual tightening of the monetary policy stance in the United States during the same period. A study conducted at the Bundesbank attempts to take into account the aspects raised as far as possible; this identifies a 4.7% depreciation in the nominal effective exchange rate of the euro and a 6.5% depreciation of the euro against the US dollar since 2014 as the aggregate effect of direct and expectation formation-related market reactions to the decisions taken by the ECB Governing Council on purchasing government bonds.

Besides the effects of the decisions to buy assets and related expectations, this article considers the potential exchange rate effects of the Eurosystem's actual purchase operations. To do this, the report presents two alternative empirical studies. Both are consistent in concluding that the Eurosystem's asset purchases themselves have not achieved any significant additional exchange rate effects beyond the cited announcement effects and corresponding expectations.

The Eurosystem's asset purchase programmes since autumn 2014

Buying asset-backed securities and covered bonds

Given repeated negative surprises with regard to the rate of inflation and declining inflation expectations in the euro area, in September 2014 the Governing Council of the ECB began taking step-by-step measures that can be summarised under the heading of "quantitative easing".[1] First, it announced the asset-backed securities purchase programme (ABPSPP) and the third covered bond purchase programme (CBPP3).[2] The net volumes of the securities acquired by the Eurosystem on the basis of these two programmes were still relatively small with monthly totals of between €1.1 billion and €13.6 billion.

Expanded asset purchase programme (APP)

In January 2015, the Governing Council of the ECB adopted the expanded asset purchase programme (APP), which comprised the public sector purchase programme (PSPP) in addition to CBPP3 and ABSPP. Given the large volume and the liquidity of the outstanding sovereign bonds, the PSPP allowed the Eurosystem to greatly expand its purchases of securities. It was initially planned that purchases under the APP would have a monthly volume of €60 billion. The programme was originally scheduled to last until September 2016 with purchases totalling €1,140 billion; in December 2015, the period was extended until March 2017, raising the intended overall volume of the programme by €360 billion. In March 2016, the monthly purchases were raised to €80 billion, which expanded the overall volume of the programme by a further €240 billion. Besides the asset classes that were already eligible, the programme now also made provision for buying bonds issued by non-bank corporations. Finally, in December 2016, a further extension of the programme's duration with monthly purchases of €60 billion between April and December 2017 was announced. This represented an additional increase of €540 billion in the intended volume of purchases.

Transmission channels of quantitative easing via the exchange rate

Impact of the programmes on price stability also contingent on the reaction of the exchange rate

The Eurosystem's asset purchase programmes cited above were adopted with the aim of bringing price developments in the euro area into line with the Governing Council's definition of price stability. How far this goal is achieved depends in part, however, on how and how strongly the euro's exchange rate reacts to the measures taken; this is because a depreciation of the euro increases the prices of imported goods, thus placing upward pressure on prices in the euro area, whereas an appreciation of the euro tends to dampen domestic inflationary pressure. Theoretically, there are various conceivable mechanisms through which quantitative easing by the Eurosystem can influence the euro's exchange rate.

Portfolio rebalancing channel

One of these mechanisms is the portfolio rebalancing channel. This posits that domestic and foreign securities are not regarded as being entirely identical (substitutable) in the eyes of investors in terms of their risk content, say, or their liquidity. Under this assumption, a bond purchase by a country's home central bank leads not only to a reduction in the bonds held in the domestic private sector, but also to an increase in the price/decline in the yield of these securities. This will prompt investors to adjust their portfolios by acquiring *inter alia* foreign bonds, thereby generating net outflows
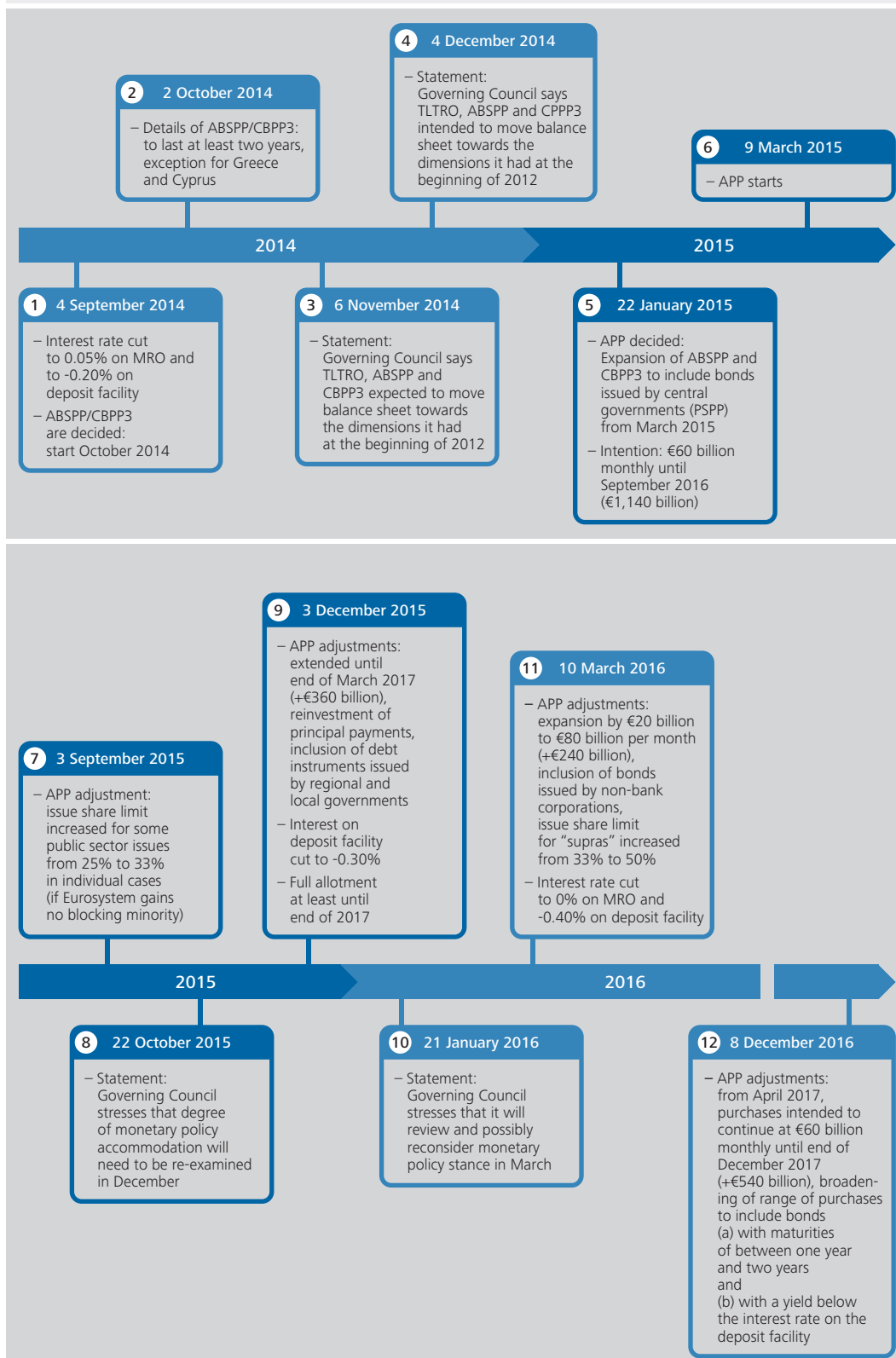
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1 A more detailed description of the Eurosystem's non-standard measures since mid-2014 is provided by Deutsche Bundesbank, The macroeconomic impact of quantitative easing in the euro area, Monthly Report, June 2016, pp 29-53.
2 There had already been various Eurosystem asset purchase programmes in earlier years as part of the monetary policy response in coping with the financial, economic and sovereign debt crisis, but their volumes were comparatively small. These include covered bond purchase programmes 1 and 2 (CBPP1 und CBPP2) as well as the securities markets programme (SMP).

Chronology of selected Eurosystem monetary policy measures since autumn 2014*

2 2 October 2014

– Details of ABSPP/CBPP3: to last at least two years, exception for Greece and Cyprus

4 4 December 2014

– Statement: Governing Council says TLTRO, ABSPP and CPPP3 intended to move balance sheet towards the dimensions it had at the beginning of 2012

6 9 March 2015

– APP starts

2014 **2015**

1 4 September 2014

– Interest rate cut to 0.05% on MRO and to -0.20% on deposit facility
– ABSPP/CBPP3 are decided: start October 2014

3 6 November 2014

– Statement: Governing Council says TLTRO, ABSPP and CBPP3 expected to move balance sheet towards the dimensions it had at the beginning of 2012

5 22 January 2015

– APP decided: Expansion of ABSPP and CBPP3 to include bonds issued by central governments (PSPP) from March 2015
– Intention: €60 billion monthly until September 2016 (€1,140 billion)

9 3 December 2015

– APP adjustments: extended until end of March 2017 (+€360 billion), reinvestment of principal payments, inclusion of debt instruments issued by regional and local governments
– Interest on deposit facility cut to -0.30%
– Full allotment at least until end of 2017

11 10 March 2016

– APP adjustments: expansion by €20 billion to €80 billion per month (+€240 billion), inclusion of bonds issued by non-bank corporations, issue share limit for "supras" increased from 33% to 50%
– Interest rate cut to 0% on MRO and -0.40% on deposit facility

7 3 September 2015

– APP adjustment: issue share limit increased for some public sector issues from 25% to 33% in individual cases (if Eurosystem gains no blocking minority)

2015 **2016**

8 22 October 2015

– Statement: Governing Council stresses that degree of monetary policy accommodation will need to be re-examined in December

10 21 January 2016

– Statement: Governing Council stresses that it will review and possibly reconsider monetary policy stance in March

12 8 December 2016

– APP adjustments: from April 2017, purchases intended to continue at €60 billion monthly until end of December 2017 (+€540 billion), broadening of range of purchases to include bonds (a) with maturities of between one year and two years and (b) with a yield below the interest rate on the deposit facility

* Abbreviations used: ABSPP = Asset-backed securities purchase programme; APP = Expanded asset purchase programme; CBPP = Covered bond purchase programme; MRO = Main refinancing operation; PSPP = Public sector purchase programme; TLTRO = Targeted longer-term refinancing operations.

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of capital which, in turn, bring about a depreciation of the domestic currency.[3]

ing the depreciation of the domestic currency induced through the other channels.

Any issuing activity weakens exchange rate effect

The described sequence of events makes it clear that the portfolio adjustment in question and the resulting depreciation of the domestic currency is initiated only if there is sufficient scope for a corresponding reduction in the yield. Declining yields, in turn, set incentives for the issuers to expand their debt and borrow additional funds through new issues. If such a reaction occurs,[4] the decline in the yield and, therefore, the effect on the exchange rate is weakened.

For quantitative easing actually to lead to the theoretically expected depreciation of the domestic currency, it is necessary for the trading partners also to allow a corresponding appreciation of the partner currencies. They might try to neutralise the expected capital inflows with their own expansionary – standard or non-standard – monetary policy measures or even introduce or strengthen capital controls. De-

Monetary policy measures by partner countries can reduce exchange rate reactions

Signalling channel

The signalling channel is a further mechanism through which asset purchases can impact on the exchange rate. This channel operates in such a way that market players could construe the announcement of quantitative easing as a signal that the monetary policy stance is going to remain expansionary for longer than previously expected and that future money market rates, too, will therefore stay low for longer. This, in turn, would bring current capital market rates under pressure. Much like with the portfolio rebalancing channel, such developments would tend to provoke net outflows of capital and a depreciation of the domestic currency.

Other channels

Besides the two channels already mentioned, a further mechanism is occasionally cited, which is also known as the "confidence channel".[5] This posits that the central bank's announcement of asset purchases can also have an impact on investors' attitude towards risk. As a result of such an announcement, for example, the view that the outlook for growth at home is less favourable than hitherto supposed might gain ground among market participants.[6] This would lead to a rise in risk premiums. Conversely, in a setting where heightened uncertainty already exists, the central bank's measures might strengthen investors' confidence, thus lowering the risk premium. This last-named effect could, all other things being equal, provoke inflows of capital, thus weaken-

3 The Governing Council of the ECB was also quick to point out such portfolio rebalancing effects having an impact on the exchange rate; as, for instance, ECB President Draghi said at the Frankfurt European Banking Congress on 21 November 2014, "Substitution of assets can also take place across jurisdictions, which would take the form of investors rebalancing portfolios away from euro-denominated assets towards other jurisdictions and currencies providing higher yields. For example, there is evidence that both the various Large Scale Asset Purchase programmes of the Fed as well as the Bank of Japan's Quantitative and Qualitative Easing programme led to a significant depreciation of their respective exchange rates, even in a situation in which long-term yields were already very low, as in Japan."
4 In actual fact, the Eurosystem's eligible assets database shows, for instance, that the outstanding volume of bonds issued by central governments in the euro area showed a net rise of €405 billion between the end of 2014 and mid-2016. More than €300 billion of this was due to net issuance by Italy, France and Spain. This contrasts with a volume of government bonds purchased under the PSPP in the total cumulative amount of €885 billion over the same period. This suggests that the programme's foreseeable effects on the yield and the exchange rate as a result of portfolio adjustments would have been perceptibly greater without this net issuance. In this connection, the German Council of Economic Experts writes in its annual report (Jahresgutachten) 2016, p 212, "Bei niedrigen Zinsen ergibt sich ein Anreiz, den Konsolidierungsprozess aufzuschieben. So könnten die bisherigen Zinssenkungen bereits zu höher als geplanten staatlichen Ausgaben beigetragen haben …" ["With low interest rates, there is an incentive to postpone the consolidation process. The interest rate cuts so far could already have contributed to public expenditure being higher than planned …".] The ECB Financial Stability Review, November 2016, p 31, states: " … fiscal reform efforts appear to have lost momentum as urgency has dwindled amid low sovereign financial market stress."
5 See M Fratzscher, M Lo Duca and R Straub (2013), On the international spillovers of US quantitative easing, ECB Working Paper 1557, as well as M Fratzscher, M Lo Duca und R Straub (2016), ECB unconventional monetary policy: market impact and international spillovers, IMF Economic Review 64, pp 36-74.
6 Such a reaction is discussed, for example, in connection with the US Federal Reserve's first asset purchase programme in 2008 and 2009, but is found not to be substantiated. See C J Neely (2011), The large-scale asset purchases had large international effects, Federal Reserve Bank of St. Louis Working Paper 2010-018C.

fensive measures of this kind are often motivated by the worry that the appreciation of their currency could impair their economy's price competitiveness or exert a deflationary impulse. If the partner currency is pegged to the euro by a fixed exchange rate, the foreign central bank is bound – on institutional grounds alone – to undertake foreign exchange interventions in order to prevent an appreciation of its currency. Monetary easing measures in partner countries that are adopted in the same period as the Eurosystem's asset purchase programmes do not necessarily have to be understood as a response to them. Global developments such as a fall in oil prices which – via second-round effects – lead to the outlook for inflation deviating worldwide from the intended target, may make expansionary policy measures seem advisable in different currency areas independently of each other.

Exchange rate reactions on the day the Eurosystem decides on the public sector asset purchase programme

Effective exchange rate of the euro based on euro foreign exchange reference rates

As information that has a bearing on exchange rates can be processed quite rapidly on the foreign exchange markets, it is to be expected that Governing Council decisions on purchasing assets are reflected in marked exchange rate movements almost as soon as they are announced. To measure this effect, the rate of change in the nominal effective exchange rate of the euro over a period of one day is often used; this is calculated as a trade-weighted average of nominal bilateral rates between the euro and a large number of other currencies. The European Central Bank fixes the euro foreign exchange reference rates on every trading day based on a point-in-time snapshot at 14.15 CET. When the decisions of the Governing Council are made public at the press conference, which starts at 14.30 following the Governing Council meeting, the time until the reference rate is determined on the next day therefore spans a period of almost 24 hours.

Of the six largest daily falls in the euro's effective exchange rate since 1999, three are closely related to the APP
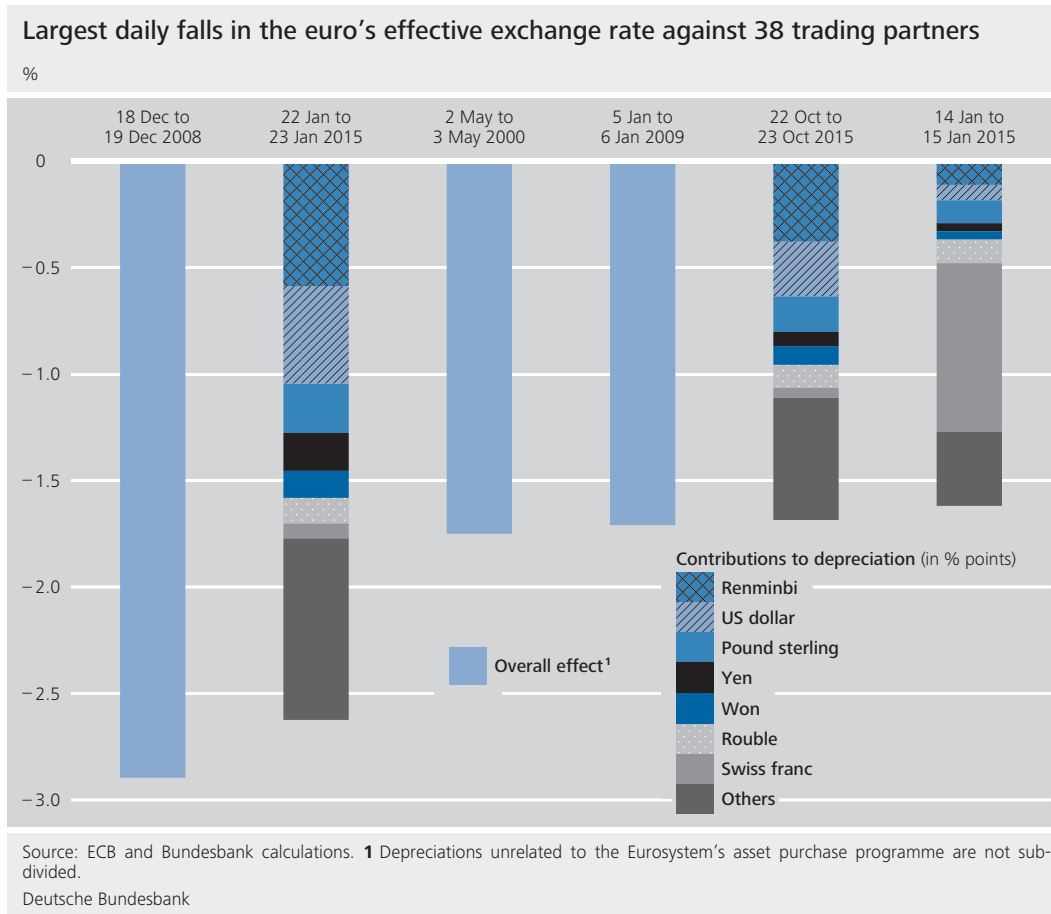
A comparison of the daily rates of change in the euro's effective exchange rate does indeed suggest that information connected with the Eurosystem's asset purchase programme can quite obviously trigger substantial exchange rate reactions over the short term. This is evident alone from the fact that, of the six largest daily falls in the euro's effective exchange rate against the currencies of 38 trading partners since the euro was launched in 1999, three are closely related to the APP.[7] For example, the euro's effective exchange rate fell by 1.7% between 22 October 2015 and the following day after the Governing Council announced that the degree of monetary policy accommodation would need to be re-examined at the December monetary policy meeting. This announcement was construed in the markets as hinting at a forthcoming monetary policy easing, perhaps also by means of marked expansion of the purchase programme. The effective exchange rate of the euro underwent a fall of a similar magnitude of 1.6% between 14 and 15 January 2015 when the Swiss National Bank discontinued the minimum rate of the Swiss franc against the euro in anticipation of the ECB Governing Council initiating a large-scale asset purchase programme.

Broad-based euro depreciation on the day of the APP decision …

However, the euro's effective exchange rate sustained a very heavy loss – of 2.6%, its second-largest loss ever – on the day the Governing Council announced the APP, ie between 22 and 23 January 2015. This strong depreciation of the euro's effective exchange rate resulted from broadly based losses against a large number of partner currencies. The currencies which have the highest weight in calculating the effective exchange rate of the euro are largely identical with those that played the largest part in the depreciation. This suggests that events outside the euro are hardly likely to have

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7 Two further falls, including the largest ever effective daily decline in the history of the euro at 2.9%, occurred at the height of the global financial and economic crisis in late 2008 and early 2009; finally, a further fall can be noted during the period of widespread scepticism about what was then still the new euro currency in spring 2000.

Largest daily falls in the euro's effective exchange rate against 38 trading partners

%

| | 18 Dec to 19 Dec 2008 | 22 Jan to 23 Jan 2015 | 2 May to 3 May 2000 | 5 Jan to 6 Jan 2009 | 22 Oct to 23 Oct 2015 | 14 Jan to 15 Jan 2015 |

Contributions to depreciation (in % points)
- Renminbi
- US dollar
- Pound sterling
- Yen
- Won
- Rouble
- Swiss franc
- Others

Overall effect[1]

Source: ECB and Bundesbank calculations. **1** Depreciations unrelated to the Eurosystem's asset purchase programme are not subdivided.

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contributed to the fall in the effective exchange rate.

… was particularly pronounced against non-European currencies …

Even so, the euro by no means depreciated uniformly against different currencies. The euro's daily loss against the US dollar amounted to 3.6%, for example, which means that 22 to 23 January 2015 also saw the euro's second-largest daily depreciation in its bilateral exchange rate against the US dollar since the single currency was introduced. Against the currencies of other major trading partners from outside Europe and Eurasia (China, Japan, Russia, South Korea and Turkey), the euro likewise depreciated by between 2.9% and 4.0%.

… but disproportionately small against west and central European currencies

Against west and central European currencies (the euro area's most important trading partners: the Czech Republic, Denmark, Poland, Switzerland and the United Kingdom), by contrast, the depreciation was consistently weaker. This was partly due to the fact that some European countries, such as Denmark, as members

of ERM II, peg their currencies to the euro and allow only very narrow fluctuations against it. The authorities of other countries intervened in the foreign exchange markets on a more or less discretionary basis against their own currencies, thus preventing them from appreciating against the euro. Finally, the high degree of economic integration within Europe may be accompanied by a stronger co-movement of the currencies concerned. This can be explained, say, by economic cycles within Europe being more synchronised than they are globally or by the national monetary policies of other European countries following the lead set by Eurosystem monetary policy.

Similar exchange rate reactions to decisions on government bond purchases in other currency areas

The extremely sharp depreciation of the euro on the day when the APP was announced, when set in the context of other times, can be compared with the exchange rate reactions when asset purchase programmes are adopted in other major currency areas. Both the Federal Reserve and the Bank of England initiated pro-

**Daily falls in selected euro foreign exchange reference rates
from 22 January 2015 to 23 January 2015**

%

West and central European currencies — Pound sterling, Swiss franc, Zloty, Czech koruna, Danish krone

Eurasian currencies — Rouble, Turkish lira

Other currencies — Renminbi, US dollar, Yen, Won

Source: ECB.
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grammes to make large-scale purchases of assets for the first time in March 2009.[8] The US dollar's effective exchange rate fell by 2.3% on 18 March 2009, the day the decision was announced.[9] As early as 5 March 2009, the Bank of England announced its decision to use the asset purchase facility. In this instance, too, there was a marked depreciation, ie a fall of 2.5% in the pound sterling's effective exchange rate, albeit only with the rate of change from the following day onwards.[10] Thus, the depreciation of the euro following the APP decision is within the range also observed in other currency areas in connection with decisions to purchase assets.

How the euro reacted to decisions to expand asset purchases

Since asset purchases under the APP commenced on 9 March 2015, the programme has been expanded considerably on three occasions, as mentioned above. The corresponding decisions were taken at the Governing Council meetings dated 3 December 2015, 10 March 2016 and 8 December 2016. The first two decisions concerned packages of measures which, besides expanding the APP, comprised a further cut in policy rates as well as additional non-standard measures. Nevertheless, the effective exchange rate of the euro was markedly higher one day after each of these decisions (by 1.6% and 1.5% respectively), whereas it was down by 1.2% one day after the Governing Council

meeting in December 2016. However, for the March date, it should be borne in mind that the Governing Council's monetary policy deci-

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8 As early as November 2008, however, the Fed had taken a decision to initiate a programme to purchase large volumes of mortgage-backed securities and direct obligations of housing-related government-sponsored enterprises.
9 In order to improve comparability, the effective exchange rate of the US dollar is calculated here against the same broad range of currencies that is used to determine the effective exchange rate of the euro. As the decisions of the Federal Open Market Committee have generally been released, since March 2013, at 14.00 Eastern Standard Time (Eastern Daylight Time), which corresponds to 20.00 Central European Time (Central European Summer Time), the observation period of just under 24 hours is reduced by roughly one-quarter when using euro foreign exchange reference rates. On the financial market effects of the first US asset purchase programme, see, for example, J Gagnon, M Raskin, J Remache and B Sack (2011), The financial market effects of the Federal Reserve's large-scale asset purchases, International Journal of Central Banking 7(1), pp 3-43; the exchange rate reactions are analysed inter alia in CJ Neely (2015), Unconventional monetary policy had large international effects, Journal of Banking and Finance 52, pp 101-111.
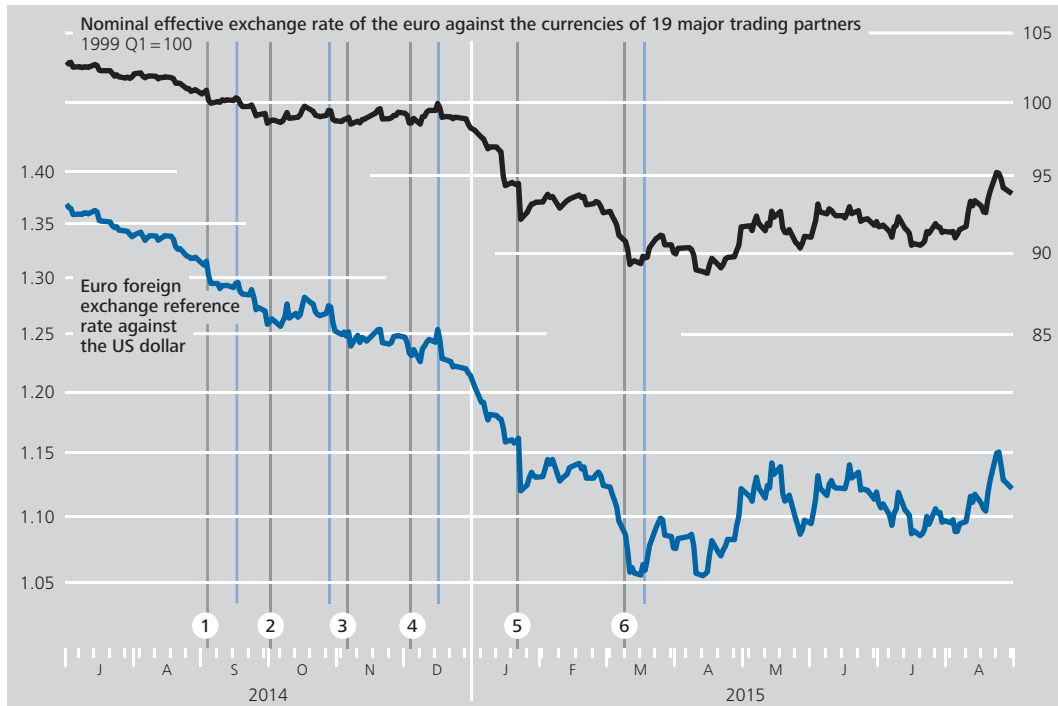**10** The rate of change amounting to -2.5% is calculated in turn from the effective exchange rates of the pound sterling against the same basket of currencies on Friday 6 March and on Monday, 9 March 2009. From 5 March to 6 March, a 0.3% appreciation of the pound sterling was recorded. Even if the depreciation of the pound sterling up to 9 March was due entirely to the Bank of England's monetary policy decisions on 5 March, a qualification that has to be borne in mind is that, simultaneously with the decision on the asset purchase facility, there was a ½ percentage point cut in the Bank of England's base rate. A detailed account of the financial market effects of quantitative easing in the United Kingdom may be found, for example, in M A S Joyce, A Lasaosa, I Stevens and M Tong (2011), The financial market impact of quantitative easing, International Journal of Central Banking 7(3), pp 113-161.

Euro exchange rate*

Daily data, log scale

Source for the time series: ECB. ***** The vertical grey lines indicate selected days on which monetary policy easing measures by the Eurosystem were recorded (see chart on p 15). The vertical light blue lines indicate selected days on which monetary policy tightening measures by the Federal Reserve Board were recorded.

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sions regarding the asset purchase programme – unlike in the past – had already been made public in a press release at 13.45, ie before the euro foreign exchange reference rates were determined at 14.15.[11] In the intervening half-hour, ie as an immediate response to the press release, the euro depreciated against major currencies. Yet even for the rate of change over two days (from 9 to 11 March 2016) there was still a 0.6% appreciation in the euro's effective exchange rate.[12] What would appear, at first glance, to be a counter-intuitive response by the exchange rate to quantitative easing can be explained, at least in part, by the fact that market participants had already been expecting expansionary measures from the Governing Council, with the impact on the euro being dictated by how far the actual measures taken differed from the previously-held expectations.

Expectation and announcement effects

Neither the decision on the APP dated 22 January 2015 nor the three aforementioned decisions to expand the programme came as a complete surprise to foreign exchange market participants. Indeed, comments by Governing Council members in the weeks leading up to said dates, in particular, induced market participants to expect a more or less substantial eas-

Expectation effects need to be considered when determining the APP's overall impact on the euro

11 Previous to this date, the substance of press releases had been confined to policy rate decisions by the Governing Council. Press releases thus contained no information on non-standard monetary policy measures. Similarly, the decision dated 8 December 2016 to extend the programme had been made public earlier (at 13.45) in a press release. Here, too, it makes sense to measure from 7 to 9 December to determine the exchange rate reaction. Over this period, the effective exchange rate of the euro depreciated by 1.0%.

12 Now proceeding to analyse the exchange rate reaction from 9 to 10 March on account of the press release would have the disadvantage of disregarding the impact on the euro of the ECB press conference on 10 March (scheduled for the usual time of 14.30), which provided further background on the decisions regarding the APP.

cont: Euro exchange rate*

Daily data, log scale

Source for the time series: ECB. * The vertical grey lines indicate selected days on which monetary policy easing measures by the Eurosystem were recorded (see chart on p 15). The vertical light blue lines indicate selected days on which monetary policy tightening measures by the Federal Reserve Board were recorded.

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ing of monetary policy. If such expectations are formed or if, in the eyes of market participants, the probability of an expected easing measure increases, this ought to be directly reflected in a depreciation of the euro.[13] On the day of the decision itself, then, the euro should have responded only to the extent that the measures taken deviate from those expected on average. This makes the euro's strong reaction on 22 January 2015 all the more remarkable. By contrast, to determine the overall impact of the asset purchase programme on the euro exchange rate, it would then be necessary, however, to consider not just the reaction to the decisions themselves, but also the exchange rate effects attributable to news from the period before the decision which had a major bearing on the formation of expectations surrounding any potential forthcoming quantitative easing measures.

Against this backdrop, it is useful to begin by considering euro exchange rate developments in the months leading up to the introduction of quantitative easing and the period since then. A corresponding time series reveals, for instance, that the euro experienced a perceptible and rather steady loss in value against the US dollar between mid-2014 and 23 January 2015, which is one day after the decision to launch the APP was taken. The euro dwindled from just under US$1.37 on 30 June 2014 to as little as US$1.12 on 23 January 2015. On balance, this equates to a depreciation of the euro by 18.0%. Although the euro suffered further marked losses in value at times (including in the first half of March 2015), the subsequent quarters saw the EUR/USD rate moved sideways, fluctuating within a range of between US$1.05 and US$1.16. The single currency came under pressure after the presidential elections in the

Developments in the EUR/USD exchange rate …

13 See, for example, T G Andersen, T Bollerslev, F X Diebold and C Vega (2003), Micro effects of macro announcements: real-time price discovery in foreign exchange, American Economic Review Vol 93, pp 38-62.

United States in November 2016 and was trading at US$1.07 as this report went to press.

… and the effective exchange rate of the euro since March 2014

Developments in the nominal effective exchange rate of the euro[14] followed a similar pattern, with the euro depreciating by 10.4% against the currencies of 19 major partner countries between 30 June 2014 and 23 January 2015. However, this exchange rate did not move as smoothly as the bilateral EUR/USD rate during this period. Thus, the effective exchange rate of the euro remained almost static on balance between mid-September and mid-December 2014, before suffering a particularly substantial loss in value up to 23 January 2015. Although the effective euro rate likewise depreciated again in the first half of March 2015, it has tended to creep up again ever since, but especially from the beginning of December 2015 onwards, with the result that the effective exchange rate of the euro of late was up by 2.6% compared with 23 January 2015.

Quantifying expectation effects difficult for several reasons

The next question concerns the extent to which developments in the euro's exchange rate during this period, in particular its sharp depreciation in the months running up to the APP decision dated 22 January 2015, can be attributed to mounting expectations in foreign exchange markets, driven by new information, that quantitative easing measures were increasingly likely in the euro area. However, quantifying the corresponding impact is extremely difficult on several counts and generally fraught with considerable uncertainty.[15]

First challenge: hard to distinguish from standard monetary policy

The quantification process quickly comes up against its first challenge because ECB press conferences or speeches by members of the Governing Council containing remarks on asset purchases normally also address standard monetary policy and, in some cases, other non-standard measures as well. Moreover, decisions on quantitative easing were, in some instances, combined with other non-standard and standard monetary policy measures. A similar situation arises when the wording of a speech points to an increase in the degree of monetary

policy accommodation without indicating whether standard or non-standard policy measures are being considered. In all these cases, it is unclear whether it was really the remarks or decisions on the APP which triggered a potentially observable depreciation in the euro.

Examples: decisions to expand APP and corresponding market expectations …

Two instances of standard and non-standard policy measures being jointly adopted were the Governing Council decisions on the expansion of the APP dated 3 December 2015 and 10 March 2016, which – as previously mentioned – also included a cut in the deposit facility rate. In the press conferences held after the respective preceding monetary policy meetings of the Governing Council on 22 October 2015 and 21 January 2016, ECB President Mario Draghi's introductory statement already contained remarks which could be interpreted as hinting at the possibility of forthcoming monetary easing measures. In his introductory statement on 21 January 2016, ECB President Draghi said the following. "It will therefore be necessary to review and possibly reconsider our monetary policy stance at our next meeting in early March […]. In the meantime, work will be carried out to ensure that all the technical conditions are in place to make the full range of policy options available for implementation, if needed." Remarks of a similar nature were also

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14 Unlike the previous section, which focused on achieving the broadest-possible geographical coverage on individual days and therefore used the nominal effective exchange rate of the euro against a broad group of 38 currencies (EER-38), the section below is based on the nominal effective exchange rate of the euro against 19 partner currencies (EER-19). This is because the official EER-38 is not available on several days owing to public holidays, which makes it unsuitable for conducting a time series analysis based on daily data. The differences between the two effective exchange rates of the euro on the individual days mentioned in the last section are minimal. The depreciation of the euro from 22 to 23 January 2015 came to 2.5% according to EER-19 (instead of 2.6% based on EER-38); the appreciation from 3 to 4 December 2015 amounted to 1.4% (instead of 1.6%), the appreciation from 9 to 11 March 2016 in both cases was measured at 0.6%, and the depreciation from 7 to 9 December 2016 was 0.9% (instead of 1.0%).
15 This is also highlighted in S D'Amico (2016), Discussion of "The financial and macroeconomic effects of the OMT announcements", International Journal of Central Banking, 12 (3), pp 59-68, for cases where expectation effects play a major role.

made on 22 October 2015.[16] That kind of wording obviously encompasses both standard and non-standard measures, with the result that any exchange rate reaction cannot be unambiguously pinned on the APP.

In response to these statements, the euro did indeed depreciate markedly – both in effective terms and bilaterally against the US dollar – from 22 to 23 October 2015 and from 21 to 22 January 2016. In effective terms against 38 major trading partners, the first of these exchange rate movements even saw the fifth-heaviest daily loss ever, as stated above. An appreciation of the euro on the dates of subsequent monetary policy meetings at which the expansionary measures were actually decided can be interpreted as a disappointment of some market participants' ambitious expectations.

… as well as decisions on ABSPP and CBPP3 in the light of high frequency data

High frequency data can sometimes provide further insight, albeit to a limited extent, into the exchange rate effects of individual measures. One example of this can be seen on 4 September 2014, when the Governing Council decided to purchase asset-backed securities and covered bonds, but also to cut policy rates by 10 basis points. This policy rate cut had already been made public at 13.45 in the form of a press release; however, the decision on the asset purchases was not announced until the press conference, which started at 14.30. The press release caused a severe exchange rate reaction. In the five minutes following its publication, the euro shed almost 1 US cent (a loss of 0.72%) against the US dollar, and there was no correction of any note in this movement by the time the press conference began. Five minutes into the press conference, the reaction was a great deal more subdued (-0.27%) and the exchange rate bounced back by half within the quarter of an hour that followed. Only after 16.30 did the euro resume a more sustained downward movement. The intra-day exchange rate movement thus implies that the euro's exchange rate over the course of 4 September 2014 was probably driven less by the Eurosys-

tem's adoption of quantitative easing, but mainly by the cut in policy rates.[17]

Second challenge: relevance of new information

Another challenge when it comes to quantifying expectation and announcement effects lies in determining the point in time at which the foreign exchange market received new information about future quantitative easing measures and which statements can even be classified as new information. Amongst other things, this concerns interviews and speeches by members of the Governing Council that only relate to quantitative easing in as far as they reiterate the substance and, in many cases, the exact wording of what has already been said else-

16 It was worded as follows. "In this context, the degree of monetary policy accommodation will need to be re-examined at our December monetary policy meeting […]. The Governing Council is willing and able to act by using all the instruments available within its mandate if warranted in order to maintain an appropriate degree of monetary accommodation."
17 While the fixing of the euro foreign exchange reference rate at 14.15 may, on the face of it, appear to be an appropriate point in time to separate the two events, the rate of change in the euro's exchange rate from 3 to 4 September 2014 contained barely half an hour's reaction to the press release, whereas the rate of change from 4 to 5 September 2014 encompassed a reaction to the press conference of almost 24 hours. In addition, it is completely unclear whether the depreciation of the euro late in the afternoon of 4 September 2014, which had a bearing on the rate of change from 4 to 5 September 2014, can be traced back to the press conference or the press release. A situation similar to that on 4 September 2014 existed in principle on 3 December 2015, when the cut in the deposit facility rate had already been made public in the press release at 13.45, but the expansion of asset purchases was not revealed until the press conference which started at 14.30. However, the above-mentioned rate of change in the foreign exchange reference rate of the euro against the US dollar from 3 to 4 December 2015 was more obviously driven by the direct exchange rate reaction at the beginning of the press conference.

EUR/USD exchange rate on days of significant Governing Council decisions on the Eurosystem's expanded asset purchase programme

Exchange rates at 5-minute intervals

Source: Bloomberg.

Deutsche Bundesbank

where, mainly at ECB press conferences.[18] In this context, information can only really be assumed to be new for the markets if market participants were expecting a different statement. In any case, it appears problematic to attribute movements in the euro's exchange rate on the corresponding days to the expectation effects of quantitative easing.[19]

Third challenge: assumptions about the window during which new information affects the euro exchange rate

There is also disagreement over the window in which it can be assumed that the observed exchange rate movement is determined exclusively or largely by the new information. On the one hand, asset prices such as exchange rates ought to respond swiftly to new information in a highly liquid market. On the other, market participants need to be granted a certain amount of time to process indications of quantitative easing or an expansion thereof, as such information will in many cases have no comparable precedents and hardly be standardised. There is no doubt that the length of this window can have quite a substantial bearing indeed on the measured overall effect of the purchase programme on the exchange rate. In the present case, this is mainly true for the period until March 2015, when the euro depreciated relatively continuously over several weeks. In event studies conducted on the impact of non-standard monetary policy measures on the exchange rate, the chosen window ranges between half an hour[20] and two days[21] in length.

Fourth challenge: impact of macroeconomic data releases …

There is a possibility, especially in cases where a longer window is used to measure how the exchange rate reacts to the announcement, that new macroeconomic data will be released during that window which also have an impact on the exchange rate. In this case, the two effects would overlap, thus distorting the estimated impact of the purchase programme. Added to this is the fact that the released data are sometimes factored into the decision-making process on monetary policy measures. This makes it even more difficult to isolate the individual effects on the exchange rate. The literature applies two alternative strategies to minimise any distortions this might cause in the results. The

first of these – as mentioned above – is to measure the exchange rate reaction in just a very short window. However, this might result in the market reaction being understated by far. For instance, movements in the euro's exchange rate over the course of the days on which the most important APP-related decisions were made do not give the impression that the response process was already over 15

… and ways of eliminating this effect

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18 One example of this is an interview which Europe 1 conducted with ECB President Mario Draghi on the morning of 24 September 2014 in which Mr Draghi, when asked about additional stimulus measures, made the following remarks. "… I can say that the Governing Council is unanimous in its commitment to use the available instruments within its mandate to bring inflation back to close to but below 2%." No further remarks concerning non-standard monetary policy were made in the interview. However, President Draghi's introductory statement to the ECB press conference on 4 September 2014 already contained the statement that "… in line with our aim of maintaining inflation rates below, but close to, 2%. … Should it become necessary to further address risks of too prolonged a period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate." From 23 to 24 September 2014, the euro depreciated by 0.5% against the US dollar. It appears doubtful whether – with reference to the interview – this depreciation can be traced back solely to a suspected increase in market participants being convinced that potential additional quantitative easing measures would be introduced in the future.
19 To get a better idea of the extent to which announcements of quantitative easing come as a surprise to market participants, some studies look at the immediate response of long-term government bond futures. Given that such measures aim at lowering long-term government bond yields, an unexpected statement in this regard – one which fuels expectations of a swift adoption of government bond purchases, say – can be expected to drive up the prices of futures of this kind. Studies which use this procedure to determine the exchange rate effects of asset purchase programmes include the following. R Glick and S Leduc (2013), The effects of unconventional and conventional U.S. monetary policy on the dollar, Federal Reserve Bank of San Francisco Working Paper 2013-11; J H Rogers, C Scotti and J H Wright (2014), Evaluating asset-market effects of unconventional monetary policy: a multi-country review, Economic Policy 29, pp 751-799; and J H Wright (2012), What does monetary policy do to long-term interest rates at the zero lower bound?, Economic Journal 122, pp F447-F466.
20 In these studies, changes in the exchange rate are measured from ten minutes before a spoken remark or publication to 20 minutes after, or from a quarter of an hour before to a quarter of an hour after such an event. See the narrow windows used in Glick and Leduc (2013), op cit, Rogers et al (2014), op cit, or E T Swanson (2015), Measuring the effects of unconventional monetary policy on asset prices, NBER Working Paper No 21816.
21 See, for example, the broad window used in Altavilla et al (2015), op cit, or Joyce et al (2011), op cit, who even use a three-day window for control purposes, amongst other things.

or 30 minutes after these decisions were made public.[22]

The second strategy for preventing macroeconomic data releases from distorting results is to explicitly factor them into estimates. Since forex market participants form expectations in advance not only over information on the monetary policy stance but also over macroeconomic data, only the surprise component of the release should be used here.[23] But this kind of approach will not necessarily eliminate the above-mentioned distortions in their entirety either because it cannot be taken for granted that the effect of macroeconomic surprises will remain constant over time,[24] and that effect might also hinge on the central bank's monetary policy stance. The response shown by the euro's exchange rate to an unexpectedly low rate of consumer price inflation, for example, might be more pronounced if the market already has the impression that the Eurosystem is considering quantitative easing measures. The chart discussed above showing the euro's heaviest daily losses, however, puts the importance of such reasoning into perspective insofar as – at least in the past few years – it was seemingly not so much macroeconomic data releases as monetary policy decisions which drove the biggest changes in the euro's exchange rate.

Fifth challenge: impact of US monetary policy

One final, materially important aspect to consider when quantifying the overall effect of quantitative easing decisions has to do with an exchange rate's function as a relative price between currencies. As such, it is determined, by its very nature, not only by the monetary policy stance in the domestic economy, but in a similar fashion by monetary policy developments abroad as well. On this score, monetary policy developments in the United States are of utmost importance, not just for the bilateral EUR/USD exchange rate but also for the effective exchange rate of the euro. The period since mid-2014, which was marked by the decisions to successively increase the degree of monetary accommodation in the Eurosystem, has seen

the US Federal Reserve gradually tighten its monetary policy. Taken by itself, this, too, acted to drive down the value of the euro, just like the Eurosystem's easing measures, with the result that the effects tended to overlap. While this is counteracted by the fact that the most important pieces of news about adjustments to the Fed's monetary policy path were not made public on the same days as those of the Governing Council, there is nonetheless a degree of risk, especially in the months leading up to March 2015, of wrongly identifying expectations regarding the Eurosystem's quantitative easing measures (rather than US monetary policy) as a significant contributor to the euro's quite steady depreciation observed at that time. That risk is intensified especially when movements in the euro's exchange rate over a comparatively long window are attributed to individual Eurosystem announcements and when very large numbers of at times relatively insignificant announcements are used to explain them.

The reasoning set out above illustrates that it is almost impossible to precisely determine the overall effect of the Governing Council's decisions regarding quantitative easing on the euro's exchange rate in a way that also takes into account the formation of expectations in foreign exchange markets. Hence, any estimate made in this regard will be fraught with a high degree of uncertainty. A study conducted at the Bundesbank which attempts to incorporate

For all the uncertainty, a drop of around 4½% in the effective exchange rate of the euro can be identified as a response to the APP decisions and earlier APP-related information

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22 For that to have been the case, the euro's exchange rate ideally ought to have levelled off once those 15 or 30 minutes had elapsed. Yet in every single instance, the exchange rate movement observed during this window instead continued beyond the window, albeit subject to some volatility.

23 Technically, this is done by deducting the median response to a survey conducted among financial market experts shortly prior to the data release from the value that is actually released, so that a surprise component remains.

24 E T Swanson and J C Williams (2014), Measuring the effect of the zero lower bound on yields and exchange rates in the U.K. and Germany, Journal of International Economics, Vol 92, pp S2-S21, therefore estimate a time-varying reaction of exchange rates to macroeconomic data releases.

Expectation and announcement effects of the expanded asset purchase programme on the euro's exchange rate: an event study

It is never easy to measure how monetary policy measures affect financial market prices with any degree of precision because market players are continually forming expectations about the future path of monetary policy, and any changes in their expectations impact directly on those prices. Analysts looking to gauge how far financial market prices have been influenced by expectation and announcement effects surrounding the expanded asset purchase programme (APP) therefore need to investigate how market expectations about the purchase programme – for example, the likelihood of it being implemented, as well as its design, possible launch date and volume – have evolved over time.

These expectations are not readily observable in practice, so analysts tend to use event studies to measure the overall effect of a policy measure on financial market variables. Event studies identify what are known as "event windows" – periods in which market opinion about a particular purchase programme might have changed. In the present case, suitable events would appear to be information made public by the ECB on the topic of the APP. Pages 22 to 26 of the main article explain why the analysis presented below is confined to ECB press conferences and press releases that follow Governing Council meetings on monetary policy matters which are very likely to have a bearing on the euro's exchange rate. Event windows are each one day long, not only to mitigate the risk of data being "contaminated" by other factors, but also to give market players enough time to react to the information made public by the ECB.

Once the relevant events have been identified, the rate of change shown by the observed variables – in this case the euro's exchange rate – between the beginning and the end of the defined event window is measured. Assuming that the information made public on the purchase programme was the sole factor influencing the exchange rate during the event window, the measured change in the exchange rate can be attributed in full to the APP. By extension, it is possible to quantify the programme's overall effect on the euro's exchange rate by adding together the changes across all the event windows.

One criticism that can be levelled at this procedure used in classic event studies is the possibility that economic metrics (concerning the unemployment rate, say, or industrial production) were made public on the same day as the events. If such information had an independent effect on the euro's exchange rate, a classic event study will deliver distorted results.

In their estimation of the effects of the Eurosystem's purchase programme on financial market variables, Altavilla, Carboni and Motto (2015) include the surprise component of a host of macroeconomic releases from the euro area and the United States in an effort to segregate that component's influence from that of the asset purchases.[1] Specifically, this approach – an event study which "controls" for macroeconomic releases – estimates the following regression for each time series under observation:

$$\Delta y_t = \sum_{i=1}^{k} \alpha_i D_{i,t} + \sum_{j=1}^{m} \gamma_j News_{j,t} + \epsilon_t$$

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1 See C Altavilla, G Carboni and R Motto (2015), Asset purchase programmes and financial markets: lessons from the euro area, ECB Working Paper No 1864.

where

$\Delta y_t = ln \ (y_t) - ln \ (y_{t-1})$ is the one-day change in the log exchange rate of the euro;

D_i is a dummy variable which takes the value 1 on the $i = 1, \dots, k$ identified event days and otherwise 0;

$News_j$ is a measure for the surprise component of $j = 1, \dots, m = 40$ macroeconomic metrics for Germany, France, Italy, Spain, the euro area as a whole and the United States.[2]

The overall effect of the purchase programme on the euro's exchange rate is then calculated as the sum of the estimated effects, transformed into a growth rate, $\hat{\alpha}_i$, on the event days – ie as $exp\left(\sum_{i=1}^{k} \hat{\alpha}_i\right) - 1$.

We will now outline the results of a study that follows the approach used by Altavilla et al (2015) but with an observation period that extends into December 2016.[3] The regression equation shown above is estimated for the euro's nominal effective exchange rate[4] and, as an alternative, for its exchange rate against the US dollar.

An event study approach will inevitably have a degree of leeway in the choice of relevant events. The present analysis makes a distinction between two phases comprising nine APP-related events in all, shown in the chart on page 15 under numbers 3-5 and 7-12. The first phase covers the APP decision on 22 January 2015 as well as two earlier press conferences in which references were made to the Governing Council's intention to take measures that would have a sizeable impact on the balance sheet (6 November 2014 and 4 December 2014). The second phase, meanwhile, encompasses press releases and press conferences for Governing Council meetings that were associated with programme adjustments

which provided additional expansionary stimulus. These comprised, first, the press conferences on 3 September 2015, 22 October 2015 and 3 December 2015, which resulted in the term of the programme being extended; second, the press conferences and press releases on 21 January 2016 and 10 March 2016, which ultimately led, *inter alia,* to the monthly asset purchase volume being increased; and, third, the press conference and press release on 8 December 2016 announcing the decision to extend the programme by nine months.[5]

Altogether, the nine monetary policy events mentioned above were associated with a considerable same-day fall in the value of the euro, even after eliminating the influence of possible macroeconomic surprises on the event days. After controlling for this influence, the estimated overall effect thus

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2 The time series were obtained from the data provider Bloomberg and express the difference between the value made public and the median analyst forecast value, divided by the standard deviation of the underlying projections. The macroeconomic metrics notably comprise releases on industrial production, the labour market and price developments.

3 The regression analysis is thus based on an observation period from 2 January 2014 to 15 December 2016. This approach differs again from Altavilla et al (2015), op cit, in that it uses a far more restrictive selection of events considered relevant, particularly in the period prior to the decision to launch the APP on 22 January 2015 and also because it explicitly takes account of the influence of US monetary policy on the euro's exchange rate. Both studies use daily data and the same series of macroeconomic surprises in their estimations.

4 The nominal effective euro rate against the currencies of 19 major trading partners of the euro area, which is calculated on the basis of the euro foreign exchange reference rates, is used here.

5 If the press conferences on 4 September 2014, 2 October 2014, 8 September 2016 and 20 October 2016 had also been factored into the analysis, they would have had relatively little bearing on the results. The estimated fall in the nominal effective euro rate would have been 0.3 percentage point larger and that of the EUR/USD rate 1.6 percentage point larger. A problem of a more fundamental nature, however, is the fact that some event days saw the announcement of other monetary policy measures unrelated to the APP. As a case in point, three-quarters of an hour before the press conference on 4 September 2014 a press release announced a 10 bp reduction in the ECB's three main policy rates.

comes in at -4.7% for the nominal effective euro exchange rate against the currencies of 19 major trading partners and at -6.5% for the euro's exchange rate against the US dollar. F tests conducted on the results indicate that both effects are significant at the 5% level.

As the adjacent chart shows, the first phase of the Eurosystem's quantitative easing measures in particular – up to and including the APP announcement – saw a distinct fall in the euro's value. Later announcements extending the term of the APP and increasing the monthly purchase volume tended to have weaker effects on the whole.[6]

These results should, however, be viewed in light of the fact that the observation period also saw the euro depreciate discernibly on days other than the event days analysed here, with the euro's effective exchange rate falling by 9.6% on balance and its ex-

Estimated controlled APP expectation and announcement effects*

%
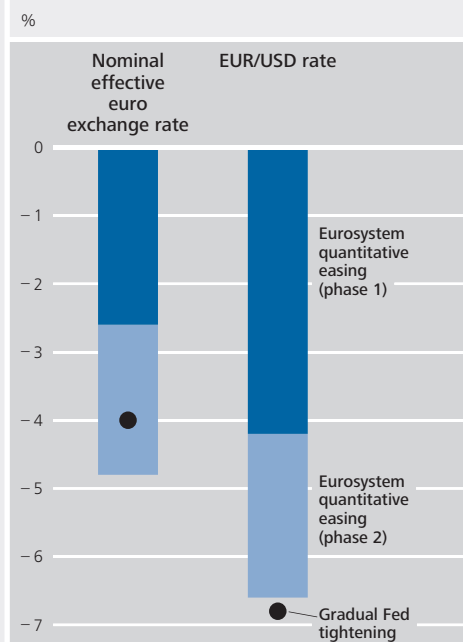
* Estimated for the period from 2 January 2014 to 15 December 2016. The influence of new macroeconomic information is included in the estimation. APP: expanded asset purchase programme.

Deutsche Bundesbank

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6 The purchase volume of the three decisions to increase the volume and extend the term of the APP totalled €1,140 billion overall, which was exactly the same volume as that of the original APP decision; however, the effect measured for the second phase is smaller than that of the first. Added to this, of the six events from the second phase, only one (on 8 December 2016) was not also connected with a standard easing of monetary policy. Thus, since the effect measured for the second phase can be traced back to a combination of policy rate cuts and quantitative easing, it must be assumed that the undeterminable, hypothetical effect of the quantitative easing alone was smaller than indicated in the estimate.
7 An exchange rate trend like the one seen primarily in the first phase observed here could be better captured by an event study, eg by also factoring a host of less obviously relevant events into the regression analysis. For instance, Altavilla et al (2015), op cit, identify 17, rather than just three, relevant events for this first phase alone. The overall effect they calculate for the first phase – a 5% euro depreciation against the US dollar – is nevertheless barely higher than the figure we come to for the same phase. But they do also report results for a two-day event window (ie exchange rate movements on two consecutive days are assigned to each of the 17 events), which means that they achieve even broader trend coverage and thus conclude that the overall effect for the first phase alone is a 12% euro depreciation against the US dollar which can be attributed to the APP.
8 While there is a series for this in the set of macroeconomic surprises, it does not contain a single surprise for the entire observation period.

change rate against the US dollar losing as much as 24.5%. This raises the question of whether what is, potentially, a substantial portion of this development might be explained by gradually mounting market expectations about the introduction and, subsequently, about the expansion of quantitative easing measures by the Eurosystem, but without necessarily being able to pin this on specific events in the shape of new information made public.[7]

However, any such considerations need to allow for the fact that the monetary policy actions of the US Federal Reserve, and not just monetary policy developments in the euro area, are likely to have had a considerable impact on the euro's exchange rate against the US dollar in particular.[8] There were mounting signs during the observation period that US monetary policy was returning to normal, culminating, first, in the tapering of and exit from asset purchases and finally, from the end of 2015, in two

Selected press releases by the Federal Reserve

Date	Substance of the Fed press release
17 September 2014	FOMC decides to slow the pace of monthly asset purchases and expects, based on its projections, the federal funds rate to be raised earlier on average in the USA.
29 October 2014	FOMC announces that the asset purchase programme will end that month.
17 December 2014	FOMC replaces the wording that it intends to maintain the federal funds rate for a considerable time after the asset purchase programme ends with the phrase that it can be patient in beginning to normalise the stance of monetary policy.
18 March 2015	First FOMC press release that does not contain the wording that it can be patient in beginning to normalise the stance of monetary policy.
28 October 2015	FOMC mentions its next meeting as a possible date for raising the federal funds rate.
16 December 2015	FOMC raises the federal funds rate.
14 December 2016	FOMC raises the federal funds rate.

Deutsche Bundesbank

policy rate hikes. Much like the Eurosystem's easing measures, a gradual tightening of the monetary reins in the United States will tend to push down the value of the euro.

The estimation seeks to model monetary policy symmetrically in the two foremost currency areas by also incorporating seven selected press releases from the US Federal Reserve which contained new information on the path of monetary policy. These releases are listed in the table above. Evidently, making this information public also sent the euro sharply lower in value. The estimated overall effect of this slight tightening of US monetary policy across both phases was a 4.0% drop in the euro's nominal effective exchange rate and a 6.8% fall in the euro's value against the US dollar (both effects being significant at the 5% level). This suggests that while events related to the Eurosystem's asset purchase programme had a major bearing on the euro's exchange rate, under no circumstances should other factors – first and foremost monetary policy in the United States – be ignored. It is therefore possible to measure this effect more accurately by confining events to those most obviously relevant to the APP and by not being overly generous in setting the length of the event window.

As a caveat, it is worth noting that the results generated with the aid of event studies of this kind should be interpreted with some caution. One reason for this was mentioned above – the fact that it is virtually impossible to clearly and unambiguously identify events relevant to the APP. Another is that the high degree of exchange rate volatility on event days makes events very sensitive to the underlying event window. The length of the event window, in particular, has a major bearing, but even if a different daily rate were used – that is, if the event window were shifted but remained 24 hours in length – the results of the estimation might be substantially different. The results presented here, for instance, are based on euro exchange rates measured at 14.15 Central European Time (CET). If rates at 23.00 CET are used instead, for example, the estimated effect of the APP on the euro's exchange rate against the US dollar is a mere -2.2% (rather than -6.5%). One possible reason for this is that these daily rates capture an exchange rate reaction over just 8½ hours (rather than almost 24 hours when euro foreign exchange reference rates are used) from the start of each ECB press conference.

the issues raised as extensively as possible[25] finds that the overall effect since 2014 of the direct and expectation formation-related market reactions to the decisions taken to date by the Governing Council on government bond purchases has been a 4.7% depreciation in the nominal effective exchange rate of the euro and a 6.5% depreciation of the euro against the US dollar.[26]

APP decision triggers large effects, programme expansions smaller ones

Much of this effect, relatively speaking (2.6 percentage points in the effective exchange rate of the euro and 4.2 percentage points bilaterally against the US dollar), is accounted for by the period up to the end of January 2015 – a spell in which market participants were increasingly anticipating government bond purchases and the APP decision was passed. The measures which expanded the programme, on the other hand, tended to have less of an impact on the euro's exchange rate. In addition, it is presumably not even possible to pin all these estimated smaller depreciation effects on the expansion of the APP as there is no way of distinguishing them from the effect of cuts in the deposit facility rate that were occasionally decided at the same time.
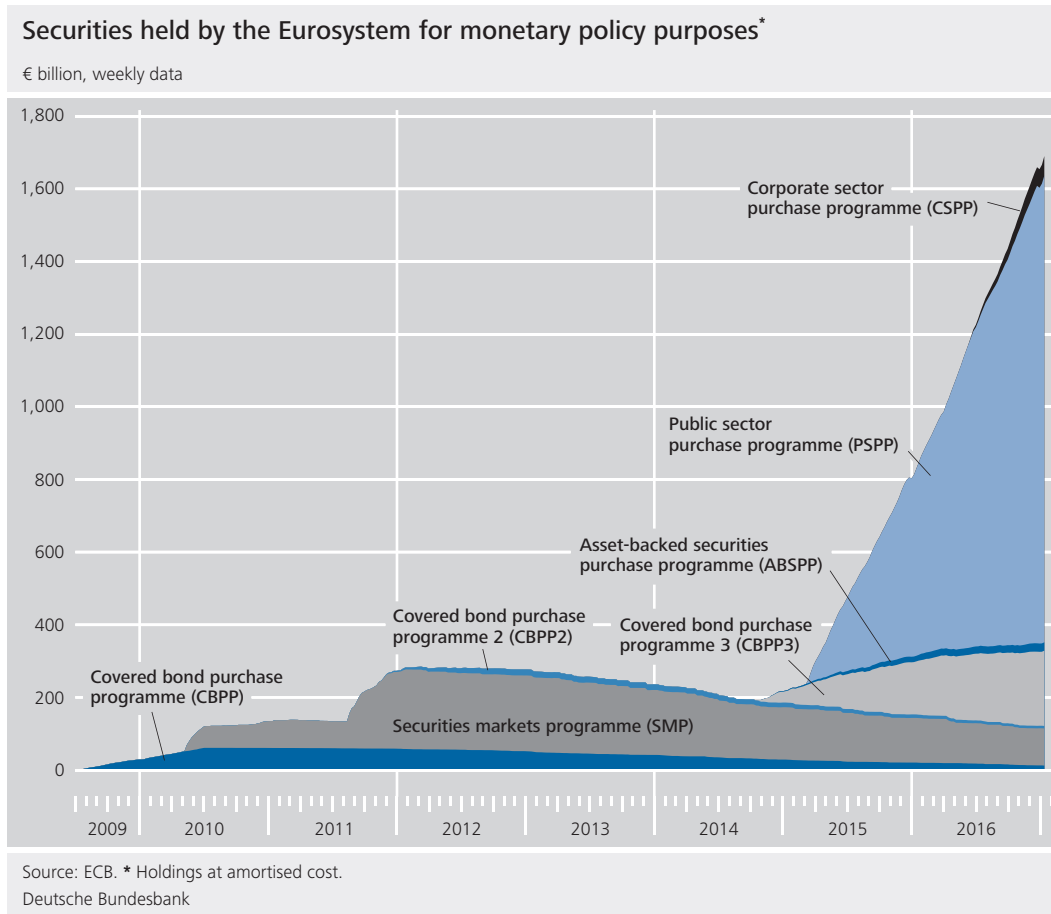
Gradual tightening of US monetary policy more or less a factor of similar magnitude in euro depreciation as APP measures

On the other hand, it cannot be ruled out that the actual exchange rate effect up until the APP decision in January 2015 was slightly larger than estimated because, as mentioned above, the study took into account only the most important pieces of new information relating to potential asset purchases. The study does, however, suggest that – compared with this lack of clarity – other factors had more of a bearing on the path followed by the euro's exchange rate. One notable such factor was US monetary policy, which was gradually tightened throughout the observation period and caused the euro to depreciate by an estimated 6.8% against the US dollar (and by 4.0% in effective terms). In terms of magnitude, this is comparable to the estimated effects of the quantitative easing in the euro area.

Analysis says nothing about the persistence of effects

When assessing the estimated announcement and expectation effects of the APP on the exchange rate of the euro, it should be noted that the present analysis does not allow any conclusions to be drawn with regard to the

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25 Following the reasoning outlined here, the change in the euro's exchange rate over the course of a trading day is attributed to a new piece of information about the APP (from the daily fixing of the euro foreign exchange reference rate prior to the announcement up to the one thereafter). All in all, this study takes nine APP-related announcements into account. As a rule, these are ECB press conferences, partly in conjunction with ECB press releases, and three of these took place in the period before the government bond purchases began in March 2015. The influence of macroeconomic data releases and US monetary policy is factored into the calculation of the effects. A detailed description of the estimation can be found in the box on pp 27-30.
26 The result is not materially different (5.0% depreciation in the effective exchange rate of the euro and 8.0% bilaterally against the US dollar) when four additional ECB press conferences, and thus inter alia all the dates listed on p 15 up until 22 January 2015, are included in the estimate. That said, even the number of nine "event days" originally selected to cover the APP decision and APP expansions appears to be rather high compared with similar studies. For example, Neely (2015), op cit, uses five event days to capture the exchange rate reaction to the adoption and expansion of the first US asset purchase programme; Joyce et al (2011), op cit, base their estimate of the effects of the first UK purchase programme, including expansions, on six event days. The overall effects we identified are considerably smaller than those cited in European Central Bank, The transmission of the ECB's recent non-standard monetary policy measures, Economic Bulletin, Issue 7/2015, pp 32-51, with reference to Altavilla et al (2015), op cit, for the period from 4 September 2014 to 5 March 2015 alone – that is to say, the period up to the beginning of the government bond purchase operations. According to that study, the APP's overall effect until that time already came to an 8% depreciation of the euro in effective terms and a 12% bilateral fall in value against the US dollar. Those findings mainly differ from the results presented here because that estimate is based on as many as 17 event days just for that short phase and because developments in the euro's exchange rate in a window as long as two days are attributed to the respective events. The study by Altavilla et al (2015), op cit, though, also presents results of an estimation based on only a window of one day for the euro's exchange rate reaction. Under this assumption, it arrives at a result which, in terms of magnitude – a 5% depreciation of the euro against the US dollar – is similar to the study presented here for the corresponding period. Another finding made in the Bundesbank study shows how far the length of the window used to measure the reaction of the euro's exchange rate influences the estimated overall effect. Using daily euro rates fixed at 23.00 instead of those at 14.15 (which implies that the period from the start of the ECB press conference at 14.30 up to the fixing of the exchange rate is distinctly shorter) results in the euro depreciating by only 2.2% overall against the US dollar, rather than by 6.5%, although the duration of the exchange rate reaction attributed to each event remains unchanged at one trading day.

Securities held by the Eurosystem for monetary policy purposes*

€ billion, weekly data

Source: ECB. * Holdings at amortised cost.
Deutsche Bundesbank

persistence of the effects identified.[27] Thus, the estimated 4.7% nominal effective depreciation of the euro may persist on a lasting basis, but it might just as well have unwound within a short space of time. This makes it more difficult to determine, for example, the extent to which a measured change in the euro's exchange rate over a given period can be attributed to the effect in question.

Effects of the asset purchase operations

Eurosystem holdings originating from purchase programmes

The expectation and announcement effects of the APP, which also include the immediate exchange rate reactions on the day of APP-related decisions by the Governing Council, need to be distinguished from the effects of putting those decisions into practice, ie those stemming from the asset purchases themselves. Government bond purchases under the APP started on 9 March 2015, while purchases of covered

bonds and asset-backed securities, which likewise form part of the broader APP programme, began back in October and November 2014 respectively. However, there is a longer observation period available to analyse the effects of asset purchase operations in the euro area, given that the Eurosystem had already conducted purchases of covered bonds and government bonds between 2009 and 2012, albeit with the primary objective back then of safeguarding the functioning of the monetary policy transmission process. Even though the Eurosystem's holdings which originated from these earlier purchase programmes are gradually receding, they still amounted to a combined total of around €185 billion at the end of 2014.[28]

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27 This point has already been stressed by Wright (2012), op cit, and also by Rogers et al (2014), op cit, with regard to the effects of quantitative easing on interest rates.
28 Purchases under the securities markets programme (SMP), which was adopted in May 2010, accounted for €144 billion of this total. Assets acquired under this programme are held to maturity, which means the holdings gradually diminish over time.

The onset of government bond purchases under the PSPP, especially, sent the Eurosystem's holdings of securities for monetary policy purposes sharply higher to €1.7 trillion, all told, by mid-January 2016.

Causes of potential exchange rate effects arising from asset purchase operations

There are some studies in the literature which assume that it is not only expectation and announcement effects, but also the actual purchases themselves, that influence variables such as the exchange rate.[29] They argue that the supply of government bonds available to private investors only decreases once the actual purchases are made, so while market participants may have been informed in advance about the point in time and volume of the intended purchases, it is entirely possible for their expectations regarding the effectiveness of these central bank operations to be fraught with uncertainty and error. Equally uncertain is the extent to which private investors reinvest the proceeds from the sale of bonds to the central bank in the alternative assets available in each case.

Distinct net sales of PSPP-eligible bonds by non-euro-area residents

The European securities holdings statistics by sector[30] can be used to gain a clearer picture of whether purchase operations under the APP triggered a portfolio shift into foreign asset holdings via the portfolio rebalancing channel, as would be expected in theory, and thus generated any downward pressure on the euro. A breakdown of the corresponding holdings shows that the holdings of euro-denominated bonds in the portfolios of investors excluding the Eurosystem declined in the one-and-a-half years between the end of 2014 and mid-2016. The statistics reveal that it was particularly non-euro-area residents which engaged in considerable net sales of PSPP-eligible bonds during this period. Sellers were chiefly private investors from the United States and the United Kingdom, the majority of whom are presumably financial sector participants. Furthermore, China's public sector (central bank and general government) decreased its holdings significantly. Assuming the proceeds from these sales were invested in non-euro-denominated assets,

this should, in itself, have exerted downward pressure on the euro. Analysis of the aggregate bond holdings which non-euro-area residents hold in custody within the euro area indicates that this may well have been the case.[31] Their holdings of euro-denominated bonds did indeed decrease sharply from the beginning of 2015 to mid-2016, while bond holdings denominated in other currencies increased markedly.

Indications of shifts out of euro-denominated bonds into other ones

Since actual purchase operations under asset purchase programmes in other currency areas have been shown to have a marked impact on the exchange rate, and because the Eurosystem's securities holdings data point to the possibility of an APP-induced shift into foreign currency bonds, the Bundesbank conducted similar analyses of Eurosystem bond purchases in an effort to measure their effect. These analyses generally take into account not just APP asset purchases but those carried out under earlier Eurosystem purchase programmes (CBPP, CBPP2 and SMP) as well. Two alternative econometric methods were used in these analyses.

Two alternative methods used for estimating the effects

The first of these is a Bayesian vector autoregression (BVAR) model. The analysis (see the box on pages 34 to 36) uses sign restrictions to identify quantitative easing measures. It concludes, however, that these accommodative measures did not significantly affect the nominal effective exchange rate of the euro during the observation period. But since this finding was achieved using monthly data, it would not

No evidence of significant exchange rate effects of Eurosystem purchase operations identified by a BVAR model, …

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29 Fratzscher et al (2013), op cit, in particular, deem the relationship between these effects to be a significant factor. They examine the Fed's first two purchase programmes and identify a distinct depreciation of the US dollar in response to the actual government bond purchases. However, they also find that the purchases of mortgage-backed securities caused the US dollar to appreciate markedly.
30 The European securities holdings statistics by sector (SHSS) comprise a sector-specific listing of all securities held in custody in the euro area. They do not capture securities held in portfolios outside the euro area.
31 However, this again is subject to the caveat mentioned above: namely, that securities which are not held in custody in the euro area are not captured by the European securities holdings statistics by sector.

Securities acquisitions within the Eurosystem's purchase programmes: a BVAR estimation of the effects on the euro exchange rate

The following analysis uses a Bayesian vector autoregression model (BVAR) to determine the quantitative effects of securities purchases by the Eurosystem on the euro's nominal exchange rate. In doing so, it essentially builds on the methodological approach used by Boeckx et al (2014), who identify a monetary policy shock predominantly by an expansion in the central bank balance sheet.[1] However, in order to isolate the effects of the purchasing programmes as precisely as possible in accordance with the initial question, our analysis modifies this approach by concentrating on the development of those balance sheet items which are determined by the purchase and redemption of securities.[2]

The VAR model used to estimate the effects of non-standard monetary policy shocks on the exchange rate of the euro can be written in reduced form as follows

$$x_t = c + \sum_{j=1}^{p} B_j x_{t-j} + u_t \text{ with } t = 1, ..., T.$$

x_t represents an (Nx1) vector with endogenous variables as described below; c denotes an (Nx1) constant and B_j an (NxN) coefficient matrix for the vector of endogenous variables lagged by j periods x_{t-j}. The (Nx1) vector u_t contains the error terms of the VAR model with $E(u_t) = 0$ and covariance matrix $E(u_t u_t') = \Omega$. As in the literature, the number of lags is set to $p = 2$.[3]

In this VAR model, the vector of endogenous variables is specified as

$$x_t = [euro_t \ asset_t \ lend_t \ mro_t \ y_t \ p_t \ vstoxx_t]',$$

where $euro_t$ represents the effective exchange rate of the euro against 19 major trading partners, $asset_t$ the Eurosystem's securities holdings for monetary policy purposes, $lend_t$ the Eurosystem's liquidity provision for monetary policy purposes, mro_t the Eurosystem's main refinancing rate, y_t the euro area's industrial production, p_t the euro area's Harmonised Index of Consumer Prices (HICP), and $vstoxx_t$ the volatility index of the stock market index Euro Stoxx 50 (VSTOXX).[4]

All the variables enter the model as logarithmic levels, with the exception of the main refinancing rate, which is modelled as a percentage. Since the Eurosystem lowered

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1 See J Boeckx, M Dossche and G Peersman (2014), Effectiveness and transmission of the ECB's balance sheet policies, CESifo Working Paper 4907.
2 The variable examined by Boeckx et al (2014), op cit, also contains balance sheet movements resulting from refinancing operations.
3 See Boeckx et al (2014), op cit and L Gambacorta, B Hofmann and G Peersman (2014), The effectiveness of unconventional monetary policy at the zero lower bound: a cross-country analysis, Journal of Money, Credit and Banking 46, pp 615-642.
4 Thus, the dataset is broadly the same as in the studies by G Peersman (2011), Macroeconomic effects of unconventional monetary policy in the euro area, CEPR Discussion Paper 8348, Gambacorta et al (2014), op cit, and Boeckx et al (2014), op cit. In contrast to these studies, however, instead of modelling the Eurosystem's overall balance sheet, the two balance sheet items "Lending to euro area credit institutions related to monetary policy operations denominated in euro" and "Securities held for monetary policy purposes" are modelled separately. The former comprises all monetary policy refinancing operations, while the latter shows the liquidity provision resulting from all the purchasing programmes. It should be noted here that the securities holdings for monetary policy purposes listed on the Eurosystem balance sheet are reported at amortised cost, and therefore only represent an approximation of the actual purchases. In order to identify a policy shock as precisely as possible, market interest rates, which may be influenced by other factors, are excluded. The data used were obtained from Datastream, Haver and the ECB's statistical data warehouse.

the deposit facility interest rate to zero in July 2012, monthly data are used for the period from July 2012 to June 2016, so that the estimations deliberately cover the period in which the zero lower bound on interest rates was significant for monetary policy. The model is estimated using Bayesian methods, with the aid of a "dummy observations prior".[5]

In order to identify a structural shock, the model is written out in structural form as

$$A_0 x_t = a + \sum_{j=1}^{p} A_j x_{t-j} + \varepsilon_t \text{ with } t = 1, ..., T.$$

A_0 represents an (NxN) matrix, where $A_j = A_0 B_j$, $a = A_0 c$ and $\varepsilon_t = A_0 u_t$. Here, $\varepsilon_t \sim N(0, I_N)$ with I_N representing a unit matrix and $E(u_t u_t') = (A'_0 A_0)^{-1} = \Omega$.

In order to identify a shock caused by quantitative easing by the Eurosystem, ie a QE shock, A_0 is chosen in accordance with Arias et al (2014)[6] in such a way that the shock generates impulse response functions which comply with particular zero and sign restrictions over a given time horizon (see chart opposite).[7] The restrictions chosen enable the shock to be attributed plausibly, and on sound economic foundations, to exogenous quantitative easing, thus separating it as clearly as possible from other shocks.

The bond purchases cause an increase in the balance sheet item "Securities held for monetary policy purposes", which is why a positive sign restriction is imposed here. In order to separate bond purchases from refinancing operations with banks[8], it is assumed that the Eurosystem's liquidity provision for monetary policy purposes does not change in the event of a QE shock. In addition, the shock is separated from conventional monetary policy shocks by assuming

Restrictions assumed to identify a QE shock

Variable	Restriction	Time horizon
$euro_t$	*	
$asset_t$	+	0–1
$lend_t$	0	0
mro_t	0	0
y_t	0	0
p_t	0	0
$vstoxx_t$	−	0–1

Restrictions: 0 = The given variable does not initially change as a result of the shock. + (−) = The given variable increases (decreases). * = No restriction is imposed. Time horizon: 0 = The restriction only applies contemporaneously, ie for the month in which the shock occurs. 0–1 = The given restriction is imposed not only contemporaneously but also for the following month.
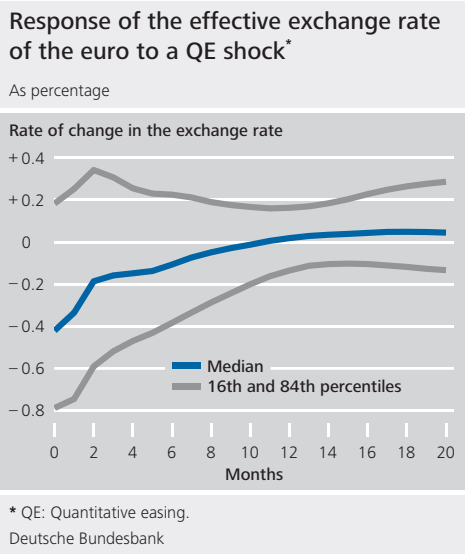
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that the main refinancing rate does not change contemporaneously. Since the estimation is based on monthly data, it is also assumed that there are no contemporaneous changes in industrial production or prices. This approach conforms to the view that these two variables only react to a monetary policy shock with a time lag. The negative sign restriction for the VSTOXX is intended to exclude the possibility that the shock might reflect an endogenous reaction

5 The dummy observations prior used is based on the Minnesota prior and expands the dataset with artificial data (dummy observations) containing the prior probability. In this case, the prior for the autoregressive coefficient is set to 1, since non-stationary data are used. The parameters for overall tightness, lag decay and exogenous variable tightness are set to 0.1, 1 and 100 respectively, in line with the usual values given in the literature. For more information, see M Bańbura, D Giannone and L Reichlin (2010), Large Bayesian vector auto regressions, Journal of Applied Econometrics 25, pp 71-92.
6 See J E Arias, J F Rubio-Ramírez and D F Waggoner (2014), Inference based on SVARs identified with sign and zero restrictions: theory and applications, International Finance Discussion Paper 1100, Board of Governors of the Federal Reserve System.
7 A total of 5,000 draws are used, following 5,000 rejected draws (burn-in).
8 This includes euro-denominated claims on credit institutions in the euro area resulting from monetary policy operations, such as, for example, main refinancing operations and longer-term refinancing operations.

Response of the effective exchange rate of the euro to a QE shock*

As percentage

Rate of change in the exchange rate

* QE: Quantitative easing.
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by the central bank to increased financial market stress.[9]

Since this report concerns the exchange rate effects of quantitative easing, only the reaction of the exchange rate will be shown here. The chart above shows the impulse response function of the exchange rate as a result of a QE shock which expands the balance sheet item "Securities held for monetary policy purposes" by an initial 1%.[10] The impulse response function gives the rate of change in the exchange rate, with the blue line representing the median reaction and the grey lines representing the 16th and 84th percentiles of the posterior distributions.

Although the impulse response function indicates that the effective exchange rate of the euro against 19 major trading partners might depreciate as a result of the identified QE shock, this effect is not significant. Our analysis, therefore, reaches a different conclusion from studies such as those by, say, Boeckx et al (2014) and Wieladek and Pascual (2016); this may be attributable to the different methods used to identify shocks.[11] As mentioned above, Boeckx et al (2014) identify a non-standard monetary policy

shock by a general expansion in the Eurosystem's balance sheet. They therefore consider a broader spectrum of monetary policy measures than securities purchase programmes alone. The fact that no significant impact was identified in our analysis, in contrast to Boeckx et al, could therefore indicate that the effects identified in the latter study are not exclusively attributable to the Eurosystem's quantitative easing measures.[12]

Wieladek and Pascual (2016), on the other hand, concentrate on announcement effects, whereas our BVAR estimation only takes into account the actual purchase operations. Therefore, the results are not directly comparable. Moreover, the present analysis covers several programmes, so that the identified effects accordingly represent an average of the various purchasing programmes implemented since 2012.

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9 A restriction of this type is also used, for example, by Gambacorta et al (2014), op cit, as well as by P Anaya, M Hachula and C Offermanns (2015), Spillovers of U.S. unconventional monetary policy to emerging markets: the role of capital flows, School of Business & Economics Discussion Paper 2015/35, Freie Universität Berlin. In the study by Boeckx et al (2014), op cit, the ECB's CISS indicator is used instead; however, this also reflects stress in foreign exchange markets. Since the present study concentrates particularly on exchange rate effects, the VSTOXX is therefore preferred. The results presented below do not change if no sign restriction is imposed on the VSTOXX.
10 This corresponds to an average growth of €3 billion.
11 For more information, see J Boeckx et al (2014), op cit, as well as T Wieladek and A G Pascual (2016), The European Central Bank's QE: a new hope, CEPR Discussion Paper 11309.
12 If the identification method used in the present study is unable to completely isolate the effects of purchasing operations from announcement effects, the estimated exchange rate reaction, which is already low, might even be overstated.

be possible to use this method to identify short-term exchange rate responses to bond purchases that subsided again over the course of a month.

… or by a regression analysis approach, …

The second econometric method used to determine the exchange rate effects of actual asset purchase operations by the Eurosystem is a regression analysis approach. This method had previously been applied in a similar fashion to analyse asset purchases carried out by the US Federal Reserve, where it provided evidence of distinct reactions in the US dollar's exchange rate.[32] One advantage of this approach is its exclusive use of financial market variables available at a high frequency, which allows it to capture short-term exchange rate reactions as well. However, when applied to the Eurosystem's asset purchase operations, this approach was likewise unable to identify a statistically significant effect on the euro's effective exchange rate (see the box on pages 38 and 39), especially when the analysis is confined to the period of government bond purchases under the PSPP.[33]

… that might have something to do with the euro's sharp depreciation before purchases started

This finding raises the question as to what factors might be driving these observations. It is conceivable, for instance, that the euro's depreciation in the period leading up to March 2015 (which saw the start of the particularly large-volume government bond purchases), a movement which is sure to have been related to expectation and announcement effects associated with the purchase programme, already included all the effects of the programme on the euro's exchange rate, including future ones, or even that it represented an overshooting on the part of the euro's exchange rate.

▮ Conclusion

Theoretical reasoning suggests that Eurosystem asset purchases ought to depress the value of the euro, and that was indeed the case on 23 January 2015, one day after the Governing Council announced the APP, when the euro's effective exchange rate sustained its second-largest fall on the day since the single currency was introduced. This is all the more remarkable given that market participants' expectations in this regard had already helped send the euro's exchange rate lower in the preceding weeks. However, it is extremely difficult to quantify the relevant effects, and thus a distinct margin of uncertainty remains.

The decisions passed by the Governing Council in December 2015, March 2016 and December 2016 to expand the asset purchases tended to exert less downward pressure on the euro, even after factoring in the exchange rate response to the formation of expectations in the market. Furthermore, there are indications that non-euro-area residents had markedly reduced their holdings of PSPP-eligible bonds on balance by mid-2016, and that they had shifted their entire asset holdings held in custody in the euro area out of euro-denominated assets into other assets. All other things being equal, this ought to have broadly put a strain on the euro. Two alternative analyses, however, suggest that the Eurosystem's actual purchase operations had no significant additional effects on the effective exchange rate of the euro.

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32 See Fratzscher et al (2013), op cit.
33 The estimated impact on the EUR/USD exchange rate was also insignificant.

Securities purchases under the Eurosystem's asset purchase programmes: a linear regression analysis of the euro's exchange rate

This article uses a regression analysis approach inspired by Fratzscher et al (2016)[1] to estimate the effects of the Eurosystem's actual purchasing operations on the effective exchange rate of the euro against 19 major trading partners. Its methodology differs from that of the study described on pages 34 to 36. One difference is that, in order to identify the effects of the Eurosystem's securities purchases, the following regression equation is estimated:

$$\Delta y_t = c + \alpha \, \Delta AS_t + \beta \Delta K_{t-1} + \varepsilon_t.$$

Let Δy_t represent the percentage change in the euro's exchange rate as a response variable. Positive values reflect an appreciation of the euro. This is regressed on a constant (c) as well as on concurrent net bond purchases (ΔAS_t) and the first difference of control variables of the preceding period (ΔK_{t-1}). The regression coefficients α and β describe the relationship between the bond purchases (or the control variables) and the euro's exchange rate; ε_t designates a disturbance term.

A second significant difference between this approach and the BVAR approach is that the current analysis is based solely on higher-frequency financial market data, meaning that it can also capture shorter-term exchange rate effects of Eurosystem bond purchases. To this end, either the daily or weekly data for the period July 2009 to June 2016 are used for the estimation. This means that the beginning of the time horizon for the analysis coincides with the beginning of the purchases of assets held by the Eurosystem for monetary policy purposes. The period is divided into several sections in order to analyse the robustness of the estimated results. Firstly, the entire period taken into account in this study is analysed. Secondly, the period during which the interest rate on the deposit facility stood at 0% or below (July 2012 to June 2016) is studied. Thirdly, the estimation is based on the period during which the Eurosystem purchased government bonds within the framework of the Public Sector Purchase Programme (PSPP), which ran from March 2015 to June 2016.

The time series for executed bond purchases is based on the holdings of securities for monetary policy purposes, which are published by the ECB in its weekly financial statements (in trillions of euro).[2] The weekly inflows and outflows are used directly for estimations made on a weekly basis. Alternatively, they are distributed evenly over the trading days in a week, as in Fratzscher et al (2013), to obtain corresponding daily data through interpolation.[3]

As the time series is virtually linear in some places (see chart on page 32), an additional indicator variable is generated for asset pur-

Control variables

Variable	Description
VSTOXX	First differences of the VSTOXX volatility index (in percentage points). Source: Datastream
Yields on ten-year bonds (euro area)	First differences of yields on ten-year government bonds in the euro area (benchmark: GDP-weighted average of issuing countries; in percentage points). Source: Bundesbank
Short-term interest rates (euro area)	First differences of a three-month OIS swap rate. Source: Bloomberg
Euro Stoxx 50	First differences of logs of the Euro Stoxx 50 index (percentage rates of change). Source: Datastream

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1 See M Fratzscher, M Lo Duca and R Straub (2016), ECB unconventional monetary policy: market impact and international spillovers, IMF Economic Review 64, pp 36-74.
2 The portfolios in the Eurosystem's balance sheet are valued at amortised cost.
3 See M Fratzscher, M Lo Duca and R Straub (2013), On the international spillovers of US quantitative easing, ECB Working Paper 1557.

Estimated values for α using alternative estimations

	Daily data		Weekly data	
Estimation period	Regressor: original time series	Regressor: indicator variable	Regressor: original time series	Regressor: indicator variable
July 2009 to June 2016	0.0234 (0.3591)	−0.0001* (−1.6577)	−0.0009 (−0.0177)	−0.0006 (−1.5562)
July 2012 to June 2016	0.0292 (0.4649)	−0.0001 (−1.4659)	0.0057 (0.1099)	−0.0006 (−1.6204)
March 2015 to June 2016	0.1984 (0.7540)	0.0005 (1.0948)	0.2127 (0.9646)	−0.0009 (−0.2578)

* = significant at the 10% level; t-statistics in brackets.
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chases. It takes the value of "1" in weeks of net asset purchases, "-1" in weeks of net reductions of bond holdings, and "0" otherwise. This series is used as an alternative to the actual time series for asset purchases.

To prevent potential endogeneity problems, only lagged values of the control variables listed in the table on page 38 are used. The control variables have the following functions within the regression analysis: VSTOXX and stock market indices cover the influence of uncertainty (market risk) on the exchange rate. Additionally, the stock price indices and the long-term interest rates can monitor expectations with regard to future economic developments. Exchange rate effects of conventional monetary policy are covered by short-term interest rates.

As financial market data time series often suffer from heteroscedasticity, the regressions for daily data are carried out with the aid of a heteroscedasticity and autocorrelation consistent estimation procedure (HAC estimator), which results in a consistent estimation of standard errors even if the assumptions of the classical regression model are violated. The OLS method is used for weekly data estimations.[4]

The results of the influence of Eurosystem asset purchases on the effective exchange rate of the euro against 19 trading partners (see table above) reveal that the relevant coefficient is generally insignificant, regardless of the selected estimation period, the data fre-

quency (daily or weekly data) or the regressor (asset purchase volumes or indicator variable). Slight indications of a significant influence appear at the 10% level if the maximum estimation period and daily data are used when applying an indicator variable. In such cases, the regression coefficient of asset purchases is negative, which corresponds to an effective depreciation of the euro in response to an expansion of bond holdings. On the other hand, if observation is restricted to the period since the beginning of PSPP asset purchases, the results are consistently positive, apart from dummy series for weekly data, and are by no means statistically significant.

On balance, the estimations cannot prove that the Eurosystem's actual asset purchase operations have affected the exchange rate of the euro.[5] However, the differing signs of the estimated coefficients for alternative estimation periods could suggest that the lack of significance is attributable to the inconclusive response of the euro to purchase operations over time.

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4 Such series of tests for heteroscedasticity (eg those of Breusch-Pagan-Godfrey and Harvey) advocate a different approach for handling daily and weekly data.
5 Estimations for which the euro-US dollar exchange rate is used as the response variable instead of the effective exchange rate of the euro present a similar picture. For this estimation, the percentage change in the S&P 500 as well as the first differences of the three-month swap rate on the US OIS rate and the yield on ten-year US Treasuries are used as control variables.