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The ECB's asset purchase programme: an early assessment

Discussion Papers

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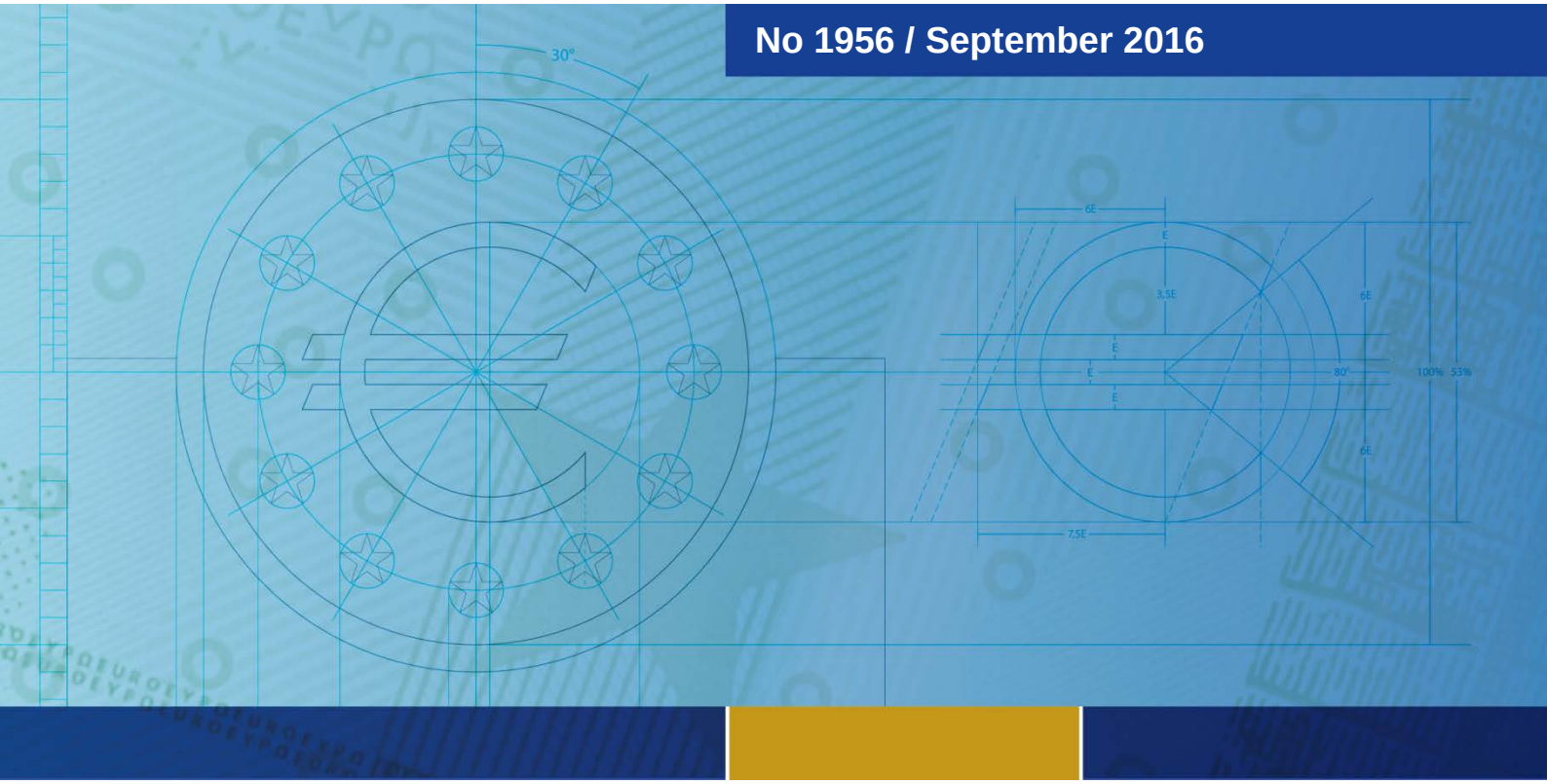

Discussion papers

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Abstract

This paper analyses the effects of the European Central Bank's expanded asset purchase programme (APP) on yields and on the macroeconomy, and sheds some light on its transmission channels. It shows, first, that the January 2015 announcement of the programme has significantly and persistently reduced sovereign yields on long-term bonds and raised the share prices of banks that held more sovereign bonds in their portfolios. This evidence is consistent with versions of the portfolio rebalancing channel acting through the removal of duration risk and the relaxation of leverage constraints for financial intermediaries. It then presents a stylised macroeconomic model that incorporates the aforementioned transmission channels. The model suggests that the macroeconomic impact of the programme can be expected to be sizable.

Keywords: Unconventional Monetary Policy, Reanchoring Inflation Expectations, Transmission of Large-Scale Asset Purchases

JEL codes: E44, E52, G12

Non-Technical Summary

In 2015 the ECB joined several other central banks in implementing "quantitative easing", through an asset purchase programme (henceforth APP) in order to address the risks of a too prolonged period of low inflation. The APP extended the ECB's existing programmes of private sector assets purchases to include purchases of sovereign bonds. This paper provides evidence suggesting that the APP was effective in easing further the stance of monetary policy in the euro area economy.

It begins with an empirical assessment of the APP on various asset prices. Two results emerge from this analysis. First, the programme produced significant effects upon announcement, on 22 January 2015. Second, such effects are estimated to persist for several months and, more specifically, for approximately as long as in the case of standard monetary policy announcements.

In terms of transmission channels, this evidence is consistent with two aspects of an "asset valuation" (or "portfolio rebalancing") channel: the reduction of duration risk and the bank capital relief.

The duration risk channel posits that the bond risk premium is increasing in the exposure of bond holders to the risk of unexpected future changes in policy interest rates. Long-duration bonds are riskier, because they are more sensitive to interest rate risk. By reducing private sector holdings of such bonds, central bank purchases should reduce exposure to duration risk and thus lead to a decline in yields. Prima facie, the evidence is consistent with this hypothesis: the fall in yields after the programme announcement is larger, the longer the maturity of bonds.

The capital relief channel suggests that the higher prices of sovereign bonds induced by the APP should benefit banks through the ensuing increased valuation of their bonds holdings. This mechanism is dubbed capital relief channel, because it is akin to a capital injection. The results in this paper provide support for the capital relief channel. They show that the equity prices of banks holding a larger portfolio share of government bonds benefited more from the increase in bond prices.

The empirical evidence is also consistent with the "signalling" channel. After the announcement of the programme, market expectations of future short term interest rates edged down, while inflation expectations tended to increase. This combined effect suggests that the downward shift in the yield curve did not reflect a worsening outlook for inflation and GDP growth.

Finally, the evidence suggests that the introduction of the APP helped the ECB guide long-term inflation expectations closer to its price stability objective. Movements in long-term inflation expectations may be due to private sectors uncertainty about the length of the horizon over which price stability will be restored. This uncertainty can produce deviations of long-term inflation expectations from levels consistent with the central banks objective. The APP

announcement appears to have reversed such tendencies. The paper therefore refers to this effect as the "reanchoring" channel.

To evaluate the macroeconomic impact of the APP, the paper relies on a general equilibrium model featuring the aforementioned, active transmission channels. Model-based results suggest that, compared to a counterfactual scenario without the APP, the purchases announced on 22 January 2015 contributed to support both inflation and output. In terms of macroeconomic effects, the programme is estimated to be roughly comparable to a decrease in standard policy interest rates by 1 percentage point.

The paper concludes with a few lessons for the implementation of the APP and some considerations on the risks it poses.

Three broad lessons can be drawn from the analysis in this paper. First, for given amount of assets purchased, macroeconomic benefits are larger, the higher the duration of the targeted assets. This lesson is a direct implication of the duration risk channel. Equivalently, effectiveness can be enhanced through purchase of corporate bonds, to the extent that the spread on such bonds is related to investors leverage constraints. These lessons are broadly in line with the evolution of the APP in 2016.

A second lesson is that the signalling channel of asset purchases can be usefully combined with a reinforced form of forward guidance. The more asset purchases are successful in leading to an upward increase in expectations of future inflation and output growth, the higher the risk that they trigger unwarranted beliefs of an earlier lift-off of the nominal interest rate from its effective lower bound. Under such circumstances, explicit forward guidance as to the likely future date of "lift-off" would be useful when implementing QE-type programmes.

The third lesson is that communication is desirable as to the future evolution of asset purchases, including the conditions for their prolongation and the plans concerning the asset portfolio at the end of the purchasing period. Model-based simulations suggest that the impact of asset purchases depends on the prevailing market assumptions about the programmes phasing off, i.e. whether the central banks asset portfolio is rolled over to avoid cliff effects, or instead liquidated as quickly as possible. From this perspective, the December 2015 Governing Council decisions ("to reinvest the principal payments on the securities purchased under the APP as they mature") provides useful information.

Concerning risks, the paper discusses, amongst others, the possible adverse effects of the APP on financial stability and the danger of capital losses for the ECB. Financial stability risks arise from the compression in spreads induced by the programme, which in the short run tends to reduce profits for banks and other financial institutions. The results in the paper suggest that this effect was probably more than compensated by the capital relief channel. Nevertheless, financially stability risks need to be carefully and continuously monitored.

Risks of capital losses for the ECB are likely to be contained, given the limited size of private sector assets purchased under the programme. Such risks should be prudently managed, but they are less likely to materialise, the more the APP is successful in strengthening the economic

recovery and in ensuring a faster return towards inflation levels consistent with the ECB's definition of price stability.

1 Introduction

On 22 January 2015 the ECB joined several other central banks in implementing "quantitative easing", or QE, through an asset purchase programme (henceforth APP) in order to address the risks of a too prolonged period of low inflation. The APP expanded the ECB's existing programmes of private sector assets purchases (the asset-backed securities purchase programme and the third covered bond purchase programme) to include purchases of sovereign bonds (through the public sector purchase programme, or PSPP).[1] This paper studies the effects of the APP on yields and on the macroeconomy, and sheds some light on its transmission channels.

We begin with an overview of the various theoretical channels of transmission of QE purchases to the macroeconomy. We group them into three main categories: the "signalling channel"; the "portfolio rebalancing channel", which we also refer to as "asset valuation channel"; and the "reanchoring channel". After a short summary of the salient features of the APP, the rest of the paper focuses on the assessment of its effects on financial markets, expectations and the macroeconomy.

We first analyse the impact effects of the APP on asset prices. We find that asset price effects are produced on announcement, i.e. when information about the ECB programme is released. No statistically significant effects can be identified when purchases are carried out. The only exception is 9 March 2015, the day when purchases started and when large asset price changes were observed. We interpret this evidence as consistent with the view that these initial purchases conveyed further information on the maturity coverage of the programme.

A key question in the empirical literature on QE concerns the persistence of the asset price effects that are typically uncovered by event studies. For the APP, we use intra-day information on the bond price reactions to APP-related Governing Council announcements as external instruments in a daily VAR. The results suggest that the effects of the APP persist for several months and, more specifically, for approximately as long as in the case of standard monetary policy shocks.

We then move on to analyse the transmission channels of the APP. Our empirical assessment of the APP starts from the asset valuation channel. We specifically focus on two aspects of the asset valuation channel: the reduction of duration risk and the bank capital relief.

Duration risk denotes the exposure of long-term bonds to unexpected changes in policy interest rates. Such risk induces a premium on bond yields. The asset valuation channel posits that the premium is a function of the stock of long-term bonds held by the private sector. By reducing the premium, central bank purchases should lead to a reduction in yields on all bonds, but especially longer-term bonds that are more exposed to duration risk. Prima facie, the evidence is consistent with this hypothesis: the fall in yields after the programme announcement is larger, the longer the maturity of bonds.

[1] A complete description of the ECB expanded asset purchase programme is available in (European Central Bank, 2015).

The capital relief channel suggests that the higher prices of sovereign bonds induced by the APP should have benefited banks through the ensuing increased valuation of the assets on their balance sheets, which was akin to a capital injection. However, lower bond yields also have adverse effects on banks through the reduced profitability deriving from a flatter yield curve. We study the relative importance of these two competing forces by looking at the reaction of banks' asset prices after the APP announcement. Since the capital relief channel should be stronger for banks holding a larger amount of sovereign bonds, we specifically test whether the equity prices of banks holding a larger portfolio share of government bonds benefited more from the increase in bond prices. Our results provide support for the capital relief channel. All in all, our analysis corroborates the empirical relevance of the asset valuation channel.

Next we study the signalling channel by investigating how private sector expectations reacted to the APP announcement. Based on the Survey of Professional Forecasters, we show that inflation and growth expectations increased after the APP announcement. We also show that disagreement in expectations of future interest rates fell, and that the fall is consistent with an interpretation of the APP as a signal of easier future monetary policy.

The analysis of survey forecasts also reveals that, after decreasing noticeably during 2014, long-term inflation expectations returned towards level consistent with the ECB's definition of price stability following the APP announcement. This evidence supports another channel of transmission, which we refer to as the reanchoring channel, which emphasises the effect of QE on long-term expectations. We specifically find support for an expectations formation mechanism such that long-term inflation expectations adjust to changes in short-term expectations.

We then use a macro model featuring these three channels to assess the likely macroeconomic effects of the APP. In our benchmark simulations, which abstract from the signalling channel, the programme contributes to stabilize the economy and push up the inflation rate. The model suggests that, compared to a counterfactual scenario without the APP, the peak increase in inflation was around 40 basis points and in output around 1.1 percent. In terms of the various channels, the asset valuation channel explains around two thirds and the reanchoring explains around one third of the peak increase in inflation compared to the counterfactual scenario.

This analysis suggests a few options to maximise the effectiveness of the APP, for given amount of asset purchases.

First, an increase in the average duration of the sovereign bonds purchased through the programme would be desirable to enhance the impact of the asset valuation channel through the removal of more duration risk from the private sector. Our results suggest that an increase in the average maturity of purchased assets from 8 to 11 years would lead to an additional increase in peak inflation by 10 basis points. An increase in the maturity of targeted assets would require abandoning the principle of "market neutrality" pursued by the ECB so far for the PSPP. Another option to enhance the impact of the asset valuation channel is to purchase riskier bonds, to the extent that the spread on such bonds is related to investors leverage

constraints. Our model simulations suggest that the purchases of private securities included in the 2015 APP play a disproportionately large role in terms of the macroeconomic impact of the programme. The 10 March 2016 Governing Council decision to launch a corporate sector purchase programme can be understood in this light.

Second, more explicit conditional commitments about future policy decisions are desirable to redress the risk of a persistent liquidity trap. From this perspective, our analysis is consistent with general lessons from the macroeconomic literature (see e.g. Woodford, 2012). Two specific aspects of these general lessons can be emphasised here.

On the one hand, an explicit form of forward guidance on the lift-off date can be desirable in combination with the asset purchase programme. The reason is that, through their expansionary effects, asset purchases can create expectations of an earlier date of "lift-off" for policy interest rates from their effective lower bound. These expectations can partly offset the beneficial effects of the programme. According to our simulations, a credible commitment to keep the lift-off date unchanged after the introduction of the programme would lead to an additional increase in peak inflation by about 5 basis points.

On the other hand, guidance is also desirable on possible future adjustments in the pace and composition of the APP as a function of evolving economic contingencies. Explicit communication on the likely evolution of the outstanding asset portfolio over the medium term would also be desirable. From this perspective, the December 2015 Governing Council decisions ("to reinvest the principal payments on the securities purchased under the APP as they mature") provides useful information.

We conclude our analysis with a discussion of the risks associated with the APP. We focus on risks for financial stability, of reduced effectiveness of the APP, and of possible losses on the ECB balance sheet. The first risk arises from the compression in spreads induced by the programme, which in the short run tends to reduce profits for banks and other financial institutions. We have already argued that this effect was probably more than compensated by the capital relief channel. In the section on risks, we also present model-based results suggesting that an asset purchase programme may remain beneficial for the economy as a whole, even if it reduced interest rate margins and slowed down banks' deleveraging. The second risk relates to the possibility of reduced effectiveness induced by governments' reaction to the purchase programme. Governments could undo the asset valuation channel, if they issued new bonds with longer maturity so as to offset the reduction in duration risk produced by the PSPP. We show that this risk has materialised only to a limited extent in the euro area, at least so far. Finally, there is a risk that the ECB will incur losses in the event of changes in the value of the assets on its balance sheet. On the one hand, losses can be expected once policy interest rates start increasing, due to the ensuing fall in the valuation of long-term bonds. Related estimates available for the US Federal Reserve suggest that the size of the losses can be expected to be small. Moreover, these losses would only be realised if the asset portfolio were not held until maturity for bonds purchased at positive yield. On the other hand, balance sheet losses

could arise in case of counterparty default, an event which can be expected to be less unlikely for the portfolio of asset-backed securities, covered and corporate bonds. This risk should be managed, but it is less likely to materialise, the more the APP is successful in strengthening the economic recovery and in ensuring a faster return towards inflation levels consistent with the ECB's definition of price stability.

2 Channels of transmission of the APP

A key difficulty in assessing the impact of asset purchase policies is that their causal impact on the economy is still imperfectly understood. A prominent view in monetary economics is in fact that asset purchases should by themselves produce no effects (see e.g. Wallace, 1981; Eggertsson and Woodford, 2003; Curdia and Woodford, 2011). The reason is that the stance of monetary policy can be fully described by the current and expected future level of the short-term policy interest rate. Once these are specified as a function of all possible future contingencies, bond prices, as well as the market prices of other financial and real assets, will adjust appropriately to reflect the present discounted stream of future returns from holding the assets. Quantitative easing amounts to a mere reallocation of such assets from private investors to the central bank. For given discounting, such reallocation does not change the present value of the returns. Central bank purchases, or equivalently expansions of the size of the central bank's balance sheet through new issuance of reserves, are thus irrelevant.

This way of reasoning leads to the conclusion that the effects of quantitative easing can only be produced indirectly, if this is interpreted as the signal that the future path of interest rates will be lower than previously intended/expected. Changes in future interest rates would evidently change the stream of future asset returns and thus their market prices. There is wide agreement on the possibility that asset purchases may produce effects through such a *signalling channel*. Under this interpretation, quantitative easing is akin to forward guidance, namely an announcement that policy interest rates will remain at the lower bound for a longer period. The marginal benefit over forward guidance is to make the announcement more credible. One explicit argument developed in the literature is that credibility is higher because large-scale purchases of long-term assets expose the central bank to the risk of losses on its balance sheet, in case short-term rates are abruptly increased. This provides an incentive for keeping policy rates low and to increase them only gradually on the exit from the crisis (see Bhattari, Eggertsson and Gafarov, 2015; Jeanne and Svensson, 2007).

The conclusion that only a change in the future path of policy interest rates can affect asset prices rests on the assumption that the marginal investor's preferences for risk are invariant to the purchases. More precisely, the assumption is that investors' valuation of the present stream of future returns from holding the assets in each possible state of the world (i.e. their "stochastic discount factor") remains unchanged. This suggests that additional effects of quantitative easing could be produced, for given expected future path of policy interest rates, if asset

purchases also led to a change in the marginal investor's valuation of future returns. This transmission channel has been dubbed "duration risk channel", to emphasise the importance of purchasing long-maturity bonds, or also "capital relief channel", because the increase in asset prices that it generates is akin to a capital injection for leverage-constrained institutions, or more generically "portfolio rebalancing channel", to highlight that a change in asset prices will lead to a change in the desired shares of those assets in investors' portfolio. Given that this channel involves a central role for changes in the valuation of expected future returns, rather than changes in the expected future returns themselves, we prefer to refer to it as an *asset valuation channel*. This also highlights that the asset valuation channel is not only present for long-term sovereigns that are perceived as default-risk free and are thus subject solely to interest rate risk. It is equally applicable to assets characterised by non-zero counterparty risk and whose market prices are impaired.[2]

A few specific mechanisms which can account for a change in asset valuations have recently been put forward in the literature. One specific mechanism producing an asset valuation channel is active when banks face funding constraints that arise endogenously as a consequence of banks' capital position (Gertler and Karadi, 2011, 2013). A policy of asset purchases replaces longer-term and/or riskier assets with short-term and safe central bank reserves. This mitigates the riskiness of banks' portfolios and allows them to increase risky loans and to reduce lending rates. The effectiveness of asset purchases under this channel is influenced by how much they ease banks' funding constraints. The easing is more pronounced, and the macroeconomic impacts are higher, through purchases of "riskier" assets (i.e. those with higher duration, higher liquidity or counterparty risk). The reallocation of these risks on the central bank's balance sheet is not neutral because the central bank does not face any funding constraints. We explicitly exploit this mechanism in the macroeconomic assessment in Section 5. An alternative mechanism leading to an asset valuation channel arises when investors are constrained by their risk bearing capacity (Vayanos and Vila, 2009), for example because they face value-at-risk constraints (Adrian and Shin, 2014). As the central bank eliminates some risk from the market through asset purchases, it induces a relaxation of the value-at-risk constraint which translates in a reduction of the market price of risk. Once again, the transfer of these risks on the central bank's balance sheet is not neutral, because the central bank does not face a value at risk constraint.

The asset valuation channel requires some form of market segmentation. One form of market segmentation gives rise to the scarcity, or safety channel, which suggests that certain securities may be demanded for reasons that go beyond their risk/return profile and are rather related to their high-liquidity characteristics. This particular component of the asset valuation channel would imply that central bank purchases narrowly affect only those assets with special liquidity characteristics.

[2] All financial assets are in general exposed to default risk in some states of the world. The asset valuation channel does not require the central bank to become unduly exposed to default risk. It only maintains that investors' *valuation* of default risk is sensitive to large central bank purchases of those assets.

A final transmission channel of asset purchases is the *reanchoring channel*. The above discussion takes for granted that there is always a unique path for expected future interest rates. A well-known theoretical risk for monetary policy actions based solely on interest rates, however, is that they may become ineffective when the lower bound constraint is reached. Private expectations may then start doubting the ability of the central bank to ensure price stability. They may at some point coordinate on a self-fulfilling, liquidity-trap equilibrium characterised by persistent deflation and deflation expectations, as well as low GDP levels (Benhabib, Schmitt-Grohe and Uribe, 2001). Given this risk, the implementation of a quantitative easing may be effective in reassuring the private sector of the central bank's ability to reanchor inflation expectations on levels consistent with price stability. An alternative mechanism to account for a reanchoring channel operates through uncertainty. If the private sector has doubts about the credibility of a central bank's medium-term inflation objective, it can try to infer any changes in the objective using currently available information. In the spirit of Gürkaynak, Sack and Swanson (2005), persistent downward deviations of inflation from the medium-term objective can thus lead to a downward revision in the perceived objective, especially if they are not accompanied by sufficiently forceful countervailing policy actions. In turn, revisions in the objective are reflected in revisions in long-term inflation expectations. This simple mechanism, which we will use in our macroeconomic simulations, can capture a potential de-anchoring of inflation expectations in periods of persistently low inflation, as well as explain why quantitative easing can help reanchor those expectations.

3 Salient features of the APP

The euro area asset purchase programme started in the fourth quarter of 2014 with the purchases of asset-backed securities and covered bonds under the ABSPP and CBPP-3, respectively. In the face of weaker than expected inflation dynamics and signs of reduction in inflation expectations even at relatively long maturities, the Governing Council decided on 22 January 2015 for the adoption of further quantitative measures to expand the size and change the composition of the Eurosystem's balance sheet. The previous two programmes were therefore supplemented with additional purchases of securities issued by euro area governments, agencies and EU institutions under the PSPP.

According to the 22 January decision, combined monthly purchases would amount to €60 billion and initially were to be carried out until at least September 2016 - and in any case until inflation returned to a path consistent with the ECB's definition of price stability. On 3 December 2015, the intended minimal duration of the programme was extended until the end of March 2017. In December 2015, the Governing Council also decided to reinvest the principal payments on the securities purchased under the APP as they mature, for as long as necessary.[3] The spectrum of securities covered by the PSPP includes only securities with a

[3] A further expansion of the APP was decided on 10 March 2016. See https://www.ecb.europa.eu/press/pr/date/2016/html/pr160310.en.html

residual maturity ranging from two to 30 years. In terms of overall breakdown, the intended allocation of the total purchases under the PSSP was 88% to government bonds and recognised agencies, and 12% to securities issued by international organisations and multilateral development banks. Purchases are to be split across eligible euro area jurisdictions according to the ECB's capital key, and conducted with the aim of maintaining market neutrality across the 2-30 year maturity spectrum.

To preserve normal secondary market functioning, purchases were initially subject to a security-specific issue-share limit of 25% and an issuer-specific limit of 33% in terms of nominal value. On 3 September 2015, the Governing Council decided to increase the security-specific limit also to 33%, subject to a case-by-case verification that it would not create a situation whereby the Eurosystem would have a blocking minority for the purposes of collective action clauses in which case the issue share limit would remain at 25%. Moreover, a blackout period around the issuance of new securities on the primary market is applied.

In line with the Eurosystem's regular monetary policy operations as well as ongoing purchase programmes, the PSPP is coordinated centrally by the ECB, but implemented in a decentralised fashion. To this end, the ECB buys directly 8% of the total amount and limits its purchases to government bonds and agency securities across all eligible jurisdictions. The remaining 92% will be purchased by national central banks, and follows a specialisation scheme whereby each national central bank (NCB) restricts its activity to domestic bonds issued by the central governments and recognised agencies of their jurisdictions. Since the recalibration of the programme in December 2015, NCBs also purchase euro-denominated marketable debt instruments issued by regional and local governments located within their jurisdiction, provided the relevant legal acts are amended. Purchases are allocated across issuers from the various euro area countries on the basis of the ECB's capital key. In case the envisaged amounts to be purchased in a jurisdiction cannot be attained, national central banks will conduct substitute purchases in bonds issued by international organisations and multilateral development banks located in the euro area. These purchases will be subsumed under the 12% allocation to international organisations and multilateral development banks, which will be purchased by some national central banks and be subject to loss sharing. Purchases of government bonds by national central banks will not be subject to loss sharing.

4 Microeconomic assessment of the APP

Before turning to a more detailed assessment of the effects of the APP, it can be instructive to assess the effectiveness of the asset purchase programmes conducted in various countries so far. One measure that has been emphasised in the applied literature is the simple impact effect of the QE announcement on the 10-year sovereign yield.

We compare the estimated effects of different QE programmes in Table 1. The table reports the median and range of the estimated impact, standardized to a size of purchases of 10 percent

of domestic GDP, based on results from 24 studies listed in Appendix B.[4] More specifically, we consider the following programmes.

- For the euro area: Expanded asset purchase programme, with a particular focus on the Public Sector Asset Purchase Programme, 03/2015-09/2016.
- For the US: Large Scale Asset Purchases 1, 12/08-03/10; Large Scale Asset Purchases 2, 11/10-06/11; and Maturity Extension Programme, 09/2011-12/2012.
- For the UK: Asset Purchase Facility 1, 03/2009-01/2010.
- For Japan: Comprehensive Monetary Easing (where "+" denotes an extended period, spanning over 12/2008-08/2011), and Quantitative and Qualitative Easing, 04/2013-09/2014.

Table 1: Impact of QE programs on 10 yrs government bond yields*

		Euro area	US			UK	Japan	
	All QE episodes	APP 03/15-09/16	LSAP1 12/08-03/10	LSAP2 11/10-06/11	MEP 09/11-12/12	APF1 03/09 - 01/10	CME+ 12/08-08/11	QQE 04/13-09/14
Size (% of GDP)		11%	12%	4%	3%	14%	21%	23%
Median	53	43	76	45	60	67	11	20
Range	10-175	27-64	32-175	33-138	23-175	34-107	10-12	14-26

*Based on results from 24 studies listed in Appendix B. The table indicates the size of the purchases conducted within each program as a share of domestic GDP, the periods when the purchases were conducted, and the median and range of the impact on 10-yrs bond yields, expressed in bps, standardized to purchases of 10% of GDP.

Two messages emerge from the table. First, the median announcement effect of a QE programme for 10 percent of GDP is to reduce 10-year sovereign yields by 53 bps. This effect should in principle refer to surprise announcements, but identifying the surprise component of QE announcements is difficult. Different papers adopt different methodologies to this end and this may account for the large range of point estimates emerging from the different studies. Second, the median effects of the APP is estimated to be of 43 basis points, i.e. only slightly smaller than the median across all episodes. This may be due to the relatively calmer financial market conditions under which the APP was implemented, compared to other programs—notably, LSAP1.

In the rest of this section, we assess in more detail the microeconomic impact of the APP. We first focus on the PSPP and study its announcement effects on sovereign bond yields, based on a detailed dataset on actual ECB bond purchases. Second, we analyse the announcement effects of the programme on the stock prices of individual banks. Third, we study whether the

[4]The median impact from the APP programme is obtained using our estimate (reported in Section 4.1.2 below) together with estimates made available by recent studies on the euro area.

effect of APP announcement on various stock prices are persistent. Finally, we investigate the impact of the programme on the expectations of professional forecasters.

4.1 The effects of the APP on individual bond yields

The APP produced clear announcement effects on asset prices (see e.g. Altavilla, Carboni and Motto, 2015). Forward interest rates, government and corporate debt yields declined, and equity prices rose. For example, 10- and 20-year government debt yields declined overnight by 14 and 19 basis points, respectively, in the case of France, and by 17 and 32 basis points in the case of Spain. Similarly, corporate bond yields (7-10 year maturity) declined by 10 basis points in case of AA-rated bonds and by 13 basis points in case of BBB-rated bonds.

This subsection delves deeper into the effects of the most sizable part of the expanded asset purchase programme, the PSPP. We use microeconomic data on purchases at the individual bond level to gauge whether the programme produced effects beyond the bonds actually purchased, or targeted, and beyond the announcement date. Testing for effects on non-targeted bonds is important to identify a scarcity channel. Effects beyond the announcement date could also signal a situation of market segmentation, such that intertemporal arbitrage is impaired.

4.1.1 Data

Our micro-database combines three data sources. First, we use the purchases of euro area bonds conducted by the Eurosystem under the PSPP at the individual bond level. Our sample covers the period from 9 March 2015 to 30 December 2015.[5] Second, we approximate the dataset of all assets eligible for purchase under the PSPP for the period both before and after the announcement using data from the ECB's collateral database.[6] [7] Third, we gather information on individual bonds from Bloomberg for all eligible bonds.

4.1.2 Effects on yields at the announcement and implementation dates

In this section, we analyze effects on bond yields of the announcement of the PSPP on 22 January 2015 and of the beginning of its implementation on 9 March 2015 on bond yields. We focus on these dates because of the associated sizable changes in euro area sovereign bond yields. Figure 1 gives an overview of the main results. The vertical lines in the graph

[5] We thank DG-M/BMI for sharing the data with us.

[6] Eligibility criteria for marketable debt securities are: (i) The securities must be denominated in Euro and issued by a central government of a member state whose currency is the euro, or by recognized agencies, development banks and international organizations located in the euro area. (ii) The issuer of the debt securities must have at least one public rating provided by an external credit assessment institution of at least Credit Quality Step 3 in the Eurosystem's harmonized rating scale (that is from BBB- onwards). (iii) If the credit assessment does not comply with at least Credit Quality Step 3, the securities are eligible only if they are issued by a member state under a financial assistance program. (iv) The securities must have a minimum remaining maturity of 2 years and a maximum remaining maturity of 30 years and 364 days. (v) Securities must have a yield to maturity above the deposit facility rate.

[7] We thank the DG-M/MOA Division at the ECB for advice on how to approximate the historical list of PSPP eligible assets.

mark the announcement and initial implementation dates, 22 January 2015 and 9 March 2015. We show that average yields (in basis points) plotted relative to the day prior to the PSPP announcement, dropped on average by about 13 basis points after the announcement and an additional 14 basis points after the implementation.[8] This effect is more pronounced for medium duration (between 5 and 10) and long duration (more or equal to 10). While medium duration bond yields appear to decline by about 12 basis points on announcement and another 14 basis point at implementation, long duration bond yields drop by about 22 basis points and about 25 basis points, respectively.

The finding of yields effects on the implementation day is striking, since all market-relevant information on the programme had been released previously, on 5 March. It is however unlikely that the yields effects on 9 March are evidence of the scarcity channel, because no yields effects are recorded further to purchases in subsequent days. We conjecture that the effects recorded after 9 March are due to the diffusion of new information such as the exact maturity distribution of the purchases, which had not previously been announced.

To compare our estimate of the impact of the PSPP to that of other QE programmes, we first compute the observed change on 10-years yields of the bonds purchased under the PSPP. This amounts to 14 basis points at announcement, and 16 basis points at implementation. Our analysis does not account for the fact that the January 22 announcement did not come as a full surprise. Bond prices most likely moved already before the January announcement in reaction to expectations of future purchases. We use survey information from Bloomberg on the expected size of the purchases under the APP before the announcement to scale the impact effect found in our analysis. On January 18, 2015, the median expectations of the size of the purchases was euros 550 bn, i.e. close to half the actual size of the programme. Our estimate of the total impact of the APP on 10-years bond yields is therefore the cumulated impact effect at announcement and implementation, where the impact at announcement is scaled by the size of the surprise (29 basis points). The total effect we impute to the events in January and March is therefore 45 bps.

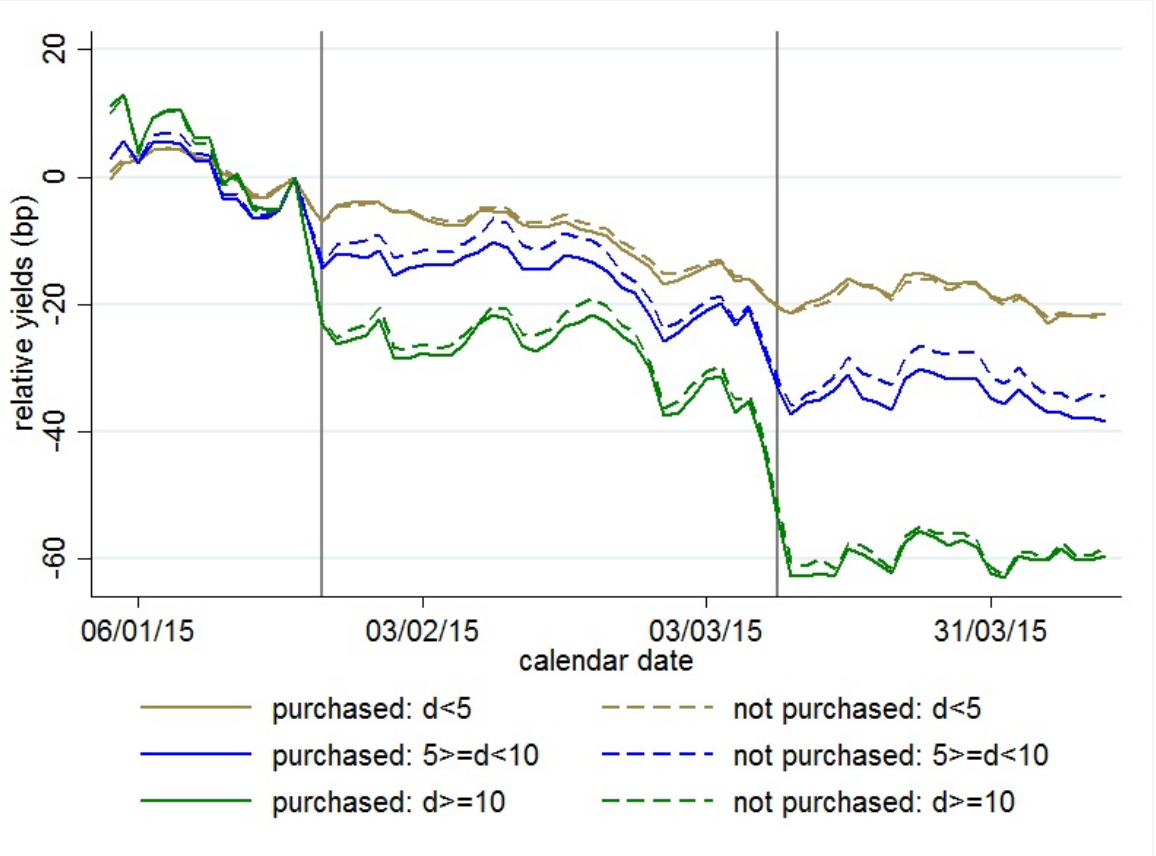
Table 2 gives a precise overview of the estimates of our event study. In column 1, we show the average effect on all bonds that are eligible and show market prices on Bloomberg. Even in this baseline model without additional controls, we can explain a significant portion of the variation with two dummies capturing the announcement and implementation effect.[9] Controlling for bond-specific non-time-varying heterogeneity between bonds, estimates of the announcement and implementation are not affected (column 2) significantly. Note that this econometric setup does not allow to control for common time effects. However, investigating cross-sectional

[8]Note that we are correcting for non-time-varying bond-specific characteristics. This, however, does not change the averages significantly.

[9]Note that the econometric approach for this event study does not influence the estimates significantly. In the reported table, the announcement dummy captures the yield changes at announcement and the day after, and the implementation dummy yield changes at the implementation and two days after. The reported results are robust against regressions with two-day and four-day steps as well as regression of the yield on the yield lagged and dummies for each implementation/announcement date (and other controls).

Figure 1: Bond yields around the PSPP announcement and implementation

This figure shows average yield (in basis points) of purchased bonds with maturities 2 - 30 years for different duration buckets relative to the day prior the PSPP announcement on 22 January 2015 correcting for non-time varying bond specific characteristics, against calendar date. Bond yields are shown separately for short duration (below 5 years), medium duration (between 5 and 10) and long duration (more or equal to 10). Each duration bucket is split further into bonds that were purchased immediately after the start of the program (within the first three days) and those we purchased thereafter. The vertical lines in the graph mark the announcement and implementation, 22 January 2015 and 9 March 2015. The sample period spans from 1 January 2015 to 17 April 2015. The graph depicts daily market yields for all bonds eligible for purchase under the PSPP.



differences allow us to include strong controls such as non-time-varying heterogeneity across bonds, daily common time effects, and common time trends within country. With these most stringent controls, we capture nearly 80% of total variation, but do not affect significantly our cross-sectional difference estimates. Column 3 (5) and 4 (6) show the regression results with and without these controls for different maturity (duration) buckets. This study is based on a panel dataset dated 22 December 2014 to 12 April 2015. The results are not sensitive towards a shorter or longer sample periods.

Our event study suggests that there is a decline in the yield for all durations/maturities with more pronounced effects for longer durations/maturities. To illustrate this, we compute simple average yields of purchased bonds for all durations/maturities, both for Italy and Germany in Figure 2. This figure plots average bond yield (in basis points) before and after the

Table 2: The PSPP announcement and implementation effect

This table reports the results from regressing the changes PSPP eligible bond yields on the announcement period, the implementation phase and the interaction terms between announcement and medium duration, announcement and long duration, implementation and medium duration, and implementation and long duration. Short duration is defined as below 5, medium duration between 5 and 10 and long duration as more or equal to 10. The announcement period is 22 January 2015 and 23 January 2015 and the implementation phase is from 9 March 2015 to 11 March 2015. The first two columns include only the announcement and implementation phase, whereas columns 3 to 6 show also differential impacts. Column 3 and 4 show differential impacts by maturity bucket, while column 5 and 6 by duration bucket. The sample period goes from 22 December 2014 to 12 April 2015. Standard errors are clustered by bond. Each column indicates whether the regression contains time (Time FE) and bond fixed effects (Firm FE) or time times country fixed effects (Time FE x Country FE). Source of data: Bloomberg.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	average effect	average effect	maturity	maturity	duration	duration
annoucement	-12.61***	-12.60***	-3.43***		-3.87***	
	(0.44)	(0.44)	(0.36)		(0.43)	
implmentation	-14.44***	-14.43***	-3.30***		-3.51***	
	(0.38)	(0.38)	(0.26)		(0.26)	
MT bond x announcement			-6.25***	-6.29***	-6.77***	-7.44***
			(0.54)	(0.48)	(0.58)	(0.44)
MT bond x implementation			-8.73***	-8.77***	-10.01***	-10.13***
			(0.42)	(0.41)	(0.43)	(0.43)
LT bond x announcement			-19.64***	-20.24***	-17.82***	-18.24***
			(0.86)	(0.63)	(0.93)	(0.68)
LT bond x implementation			-22.82***	-22.97***	-21.07***	-21.82***
			(0.42)	(0.40)	(0.55)	(0.49)
Observations	26,976	26,976	26,976	26,976	26,976	26,976
R-squared	0.249	0.268	0.374	0.797	0.357	0.777
-	-	-	-	-	-	-
Bond FE	NO	YES	YES	YES	YES	YES
daily Time FE	NO	NO	NO	YES	NO	YES
Time x Country FE	NO	NO	NO	YES	NO	YES
-	-	-	-	-	-	-
Cluster Bond	YES	YES	YES	YES	YES	YES

*** p<0.01, ** p<0.05, * p<0.1

announcement and implementation of the PSPP. The two plots on the top show duration and the two at the bottom maturity. The yield curves around the announcement date refer to 21 January 2015 and 23 January 2015, while the yield curves around the implementation date refer to 6 March 2015 and 10 March 2015.

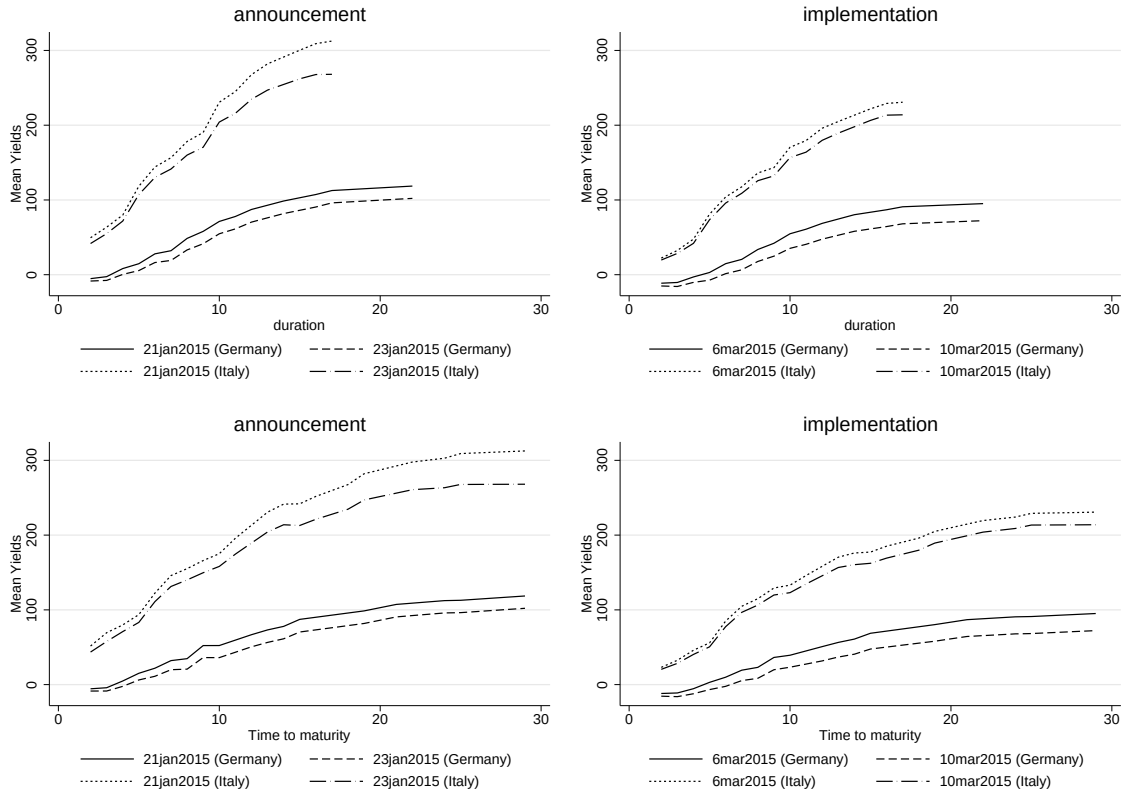
Both at announcement and implementation, the yields at all maturities/durations shift downwards, but the shift is more pronounced for longer maturity/duration yields. This is prima facie evidence in favour of the duration channel.

4.1.3 Effects on yields from purchases and market segmentation

Besides depicting the differential effects at announcement and implementation in Figure 1, we also distinguish between bonds that were purchased within the first three trading days after the start of the program and bonds that were not immediately bought by the Eurosystem but that were eventually bought later in the course of the program. We find that the changes in yields for those bonds the Eurosystem actually bought and those not bought are not significantly different from each other. This does not lend support to the hypothesis of a scarcity. It should

Figure 2: Yield curves around announcement and implementation

This figure plots average bond yield (in basis points) Italy and Germany before and after the announcement and implementation of the PSPP. The two plots on the top show duration and the two at the bottom maturity. The yield curves of the announcement are as of 21 January 2015 and 23 January 2015, while the yield curves for the implementation are as of 6 March 2015 (Friday) and 10 March 2015 (Monday). The data source for daily yields is Bloomberg with a sample size of PSPP eligible bonds purchased that were eligible for purchase as of 9 March 2015.



be noticed, however, that the bonds that were initially not purchased belonged to the set of eligible assets for the PSPP. It cannot be excluded that the yields of eligible bonds fell in anticipation of future purchases, rather than as a result of arbitrage in bond markets.

We further test whether actual purchases by the Eurosystem have significant effect on individual bond yields with three different regression analyses.

First, we conduct a simple panel regression analysis by regressing changes in bond yields on bond purchase dummies. Our result suggests that there is no significant difference within and across bonds when the Eurosystem purchases. Table 3 column 1 to column 4 report the results. Since the implementation period is special, in particular on how many bonds are purchased for the first time, we focus on the period after the first week of implementation. In column 1 and column 2 the purchase effect is a dummy variable indicating whether or not the Eurosystems bought a specific bond on a particular day. Column 3 and column 4, on the

other hand, measure purchases as the amount purchased on a given day relative to the amount outstanding (in percentages). Our estimates also suggest that there is little if any significant cyclicality during the 2015 purchases. Purchases had similar effects on yields over the horizon of the program as suggested by columns 2 and 3.

Second, our analysis suggests that yields are not significantly more affected when the Eurosystem purchases more intensively. Our difference-in-differences analysis around the first purchase of individual bonds allows us to estimate differential effects between bonds purchased relatively less and bonds purchased relatively more. Column 2 and column 3 of Table 3 report estimation results for event windows of one week before and one week after the first purchase. The purchase intensity variables are dummy variables indicating how much of some bonds was bought relative to other bonds during the first week of purchase.[10] All estimates are insignificant suggesting that there is no differential impact on bonds that were purchased most. Note that the estimates are not only insignificant, but also very small and do not increase with purchase intensity. As for the first test, we use only data as of the second week after the start of the purchases to ensure that the results are not driven by the first days of the programme.

One caveat is warranted: the decision by the Eurosystem to buy a specific bond could be motivated by the relatively lower price of that bond. The purchase could increase the price and lower the yields. Indeed, the yield of a purchased bond might not significantly differ from the yields of not purchased bonds precisely as a consequence of the purchase carried out by the Eurosystem.

The design of the PSPP programme allows us to mitigate this concern a bit further. Our third test exploits the fact that newly issued bonds are subject to a publicly unknown blackout period during which no purchases are allowed. We conduct a difference analysis around the end of the blackout period and find no significant effect on bond yields. Table 3, column 4 reports these results. This suggest that already at issuance by the time when the bond is not yet eligible and not yet purchased, yields are not significantly different. Nevertheless, it should be noticed that the blackout period is non-binding, i.e. once it ends the Eurosystem does not necessarily start trading immediately.

4.2 The impact of the APP on euro area banks

Banks are expected to play a central role in the transmission of large-scale asset purchases. As leveraged institutions, they benefit from an increase in the value of the assets on their balance sheet because, for given liabilities, the increase translates into higher capital/net worth–an effect described as "stealth recapitalisation" in the literature. In turn, higher net worth releases the stringency of leverage constraints, leading to easier lending conditions, a faster recovery

[10]This analysis is robust against different event windows around the first purchase and different relative measures of trading intensity (e.g., relative amount purchased, or number of trading days active). We find similar results applying a difference estimation setup.

Table 3: Yield impact of bond purchases

This table reports regression results on how purchases under the PSPP affect bond yields. The first row shows how bond yields are affected by purchases under the PSPP. The dummy variable purchase effect is equal to 1 if a bond is purchased on this day and it is equal to zero otherwise. In columns 3 and 4 the variable purchase effect gives the amount purchased by the Eurosystems relative to the outstanding amount of the bond (in percentages). The fifth and sixth columns report how bond yields are affected by the first purchase under the PSPP. The dummy variable treatment effect is equal to 1 when a bond has been purchased for the first time and in the week after, and zero for the week before and for bonds not purchased. Column 6 reports differential impact depending on the amount purchased during the week following the first purchase. Column 7 reports how bond yields are affected when a newly issued bond passes the blackout period during which the Eurosystem is not buying the bond. The dummy variable is equal to 1 for a few days after the blackout period ends and zero for the period before. There are 78 new issuance considered. The overall sample period includes purchases from 16 March 2015 to 30 December 2015. Standard errors are clustered by bond. Each column indicates whether the regression contains time (Time FE) and bond fixed effects (Firm FE). Source of data: Bloomberg, ECB purchases database, and ECB eligibility database.

	Trading effect				First purchase effect		Blackout period effect
	purchase dummy		relative purchases				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
purchase effect	-0.021	0.059	0.019	-0.368	-0.045	0.047	0.862
	(0.041)	(0.087)	(0.038)	(0.327)	(0.088)	(0.200)	(1.310)
purchase intensity (perc.25–50)						0.016	
						(0.255)	
purchase intensity (perc.50–75)						-0.278	
						(0.265)	
purchase intensity (perc.75–100)						-0.094	
						(0.265)	
purchase effect × April		0.317		0.446			
		(0.257)		(0.339)			
purchase effect × May		0.067		0.666*			
		(0.110)		(0.362)			
purchase effect × June		0.029		0.680*			
		(0.119)		(0.349)			
purchase effect × July		-0.481***		0.266			
		(0.114)		(0.342)			
purchase effect × Aug		0.105		0.363			
		(0.095)		(0.332)			
purchase effect × Sep		-0.278**		0.332			
		(0.139)		(0.349)			
purchase effect × Oct		-0.216**		0.368			
		(0.097)		(0.334)			
purchase effect × Nov		-0.285***		0.269			
		(0.099)		(0.335)			
purchase effect × Dec		0.236**		0.166			
		(0.108)		(0.418)			
Observations	913,091	913,091	913,044	913,044	774,051	774,051	434
R-squared	0.0236	0.0236	0.0236	0.0236	0.0251	0.0251	0.6261
-	-	-	-	-	-	-	-
Bond FE	YES	YES	YES	YES	YES	YES	YES
daily Time FE	YES	YES	YES	YES	YES	YES	YES
-	-	-	-	-	-	-	-
Cluster Bond	YES	YES	YES	YES	YES	YES	YES

*** p<0.01, ** p<0.05, * p<0.1

and higher prospective bank profits through a prospective reduction in non-performing loans. These effects should be stronger for banks with larger sovereign bond holdings.

In this section we look for direct evidence of this effect with a particular focus on the PSPP.

We study the differential impact of individual banks stock prices to PSPP-related announcements. Our main testable hypothesis is that equity prices should increase more, the larger the share of sovereign bonds in the bank's balance sheet. In doing so, we control for the following factors.

First, the PSPP can be expected to have a negative impact on banks' interest rate margins. With short rates fixed at their lower bound, a reduction of long term interest rates is tantamount to a flattening for the yield curve. Since banks engage in maturity transformation, a flattening of the yield curve should, ceteris paribus, reduce their profitability.

Second, we control for the impact of the signalling channel, which would also tend to increase stock prices. To the extent that the PSPP is understood as a signal of easier future monetary policy conditions, it should also be accompanied by higher discounting of future profits. This channel should lead to an increase in stock prices even for given expected future profits. The increase should be even larger, if expected future profits also increased due to the overall improvement in macroeconomic conditions.

Finally, it is to be expected that the PSPP will have differential effects on banks, depending on their capitalization. Well-capitalised banks would be able to benefit from the higher valuation of their assets. In contrast, less well-capitalized banks would continue being subject to regulatory or market pressure. The present discounted value of their expected future profits may thus be insensitive to the PSPP.

We rely on the event study methodology. For a given PSPP announcement date, we associate the observed changes in banks' stock prices with the PSPP surprise. We focus on two dates: 22 January 2015, when the PSPP decision was publicly communicated; 5 March 2015, when further details of the programme were announced.

We relate the equity price changes to a number of aggregate and bank-specific explanatory variables. Given our focus on individual banks' stock prices, some of which may be less actively traded, our results are based on 2-day stock price changes.

As explanatory variables, we use: (1) banks' holdings of sovereign bonds, to capture the direct effect of changes in bond prices on their balance sheets; (2) proxies for general economic conditions in each country, which should capture the expected impact on banks of the improved economic outlook; (3) the change in national bond yields following the PSPP announcement, which represents a measure of the change in the slope of the yield curve; (4) proxies for banks' capitalization levels.

Concerning banks' holdings of sovereign bonds, we rely on two different sources: SNL, which covers more banks and has up-to-date information based on end-2014 balance sheets, but includes less detail on the country and maturity composition of sovereign bond holdings; the EBA stress test of 2014, which covers fewer and larger banks, is based on end-2013 information,

but has more precise coverage in terms of key characteristics of the sovereign bonds held by banks.

Our analysis yields 3 main results.

1. We do find that the share of sovereign bonds on a bank's balance sheet has explanatory power to account for changes in the bank's stock price after the PSPP announcement. As expected, a bank's stock prices increase more, the higher its exposure to sovereign bonds. This effect is statistically significant for the SNL sample of banks; it is only occasionally significant for the smaller EBA sample.
   This evidence is supportive of the asset valuation channel for sovereign bond purchases. The increase in bank capital releases leverage constraints and thus creates space for a reallocation of portfolios towards other risky assets, including lending. In turn, an expansion in lending should foster the recovery and help prevent deflationary pressure.

2. We also find that banks' stock prices tend to increase more, the larger the increase in their country's overall stock price index. This effect suggests that the PSPP announcement led to a perceived improvement in the general economic outlook, thus to higher stock prices in all sectors of the economy. In turn, an improved outlook should be associated with higher credit demand and eventually higher bank profits.

3. At the same time, we find evidence of adverse effects of the PSPP on banks' profitability through two proxies. The first proxy is a euro area dummy, which is negative and significant. It suggests that, for given exposure to sovereign bonds, banks' stock prices tended to increase less for banks located in the euro area, i.e. banks which can be expected to be more sensitive to a fall in profitability associated with a lower yield curve slope. The second proxy is the fall in long term sovereign yields following the PSPP, which is a more direct measure of the change in the slope of the yield curve. The increase in individual bank stock prices is lower, the larger the fall in sovereign bond yields of the country where the bank is located.

In the rest of this section, we describe our results in more detail.

4.2.1 Data

We include in our sample all listed banks for which publicly available balance sheet information is available on their holdings of sovereign bonds. We however exclude Greek and Cypriot banks from the sample, because their stock market prices were extremely volatile over the PSPP announcement period. The total number of banks is 120 for the SNL dataset and 51 for the EBA dataset.

Table 4: Summary table for 2-day price changes

	21-23 January			4-6 March		
	mean	median	std. dev.	mean	median	std. dev.
Full SNL sample:						
equity return	1.19	0.99	2.79	0.96	0.64	3.68
exposure[1]	12.00	10.11	11.77	12.00	10.11	11.77
Δ yield (10y)[2]	-0.19	-0.16	0.18	-0.01	0.00	0.08
Δ SM [2]	1.56	1.54	1.99	0.90	0.91	1.46
STOXX Europe 600 return	3.36			0.91		
STOXX Europe 600 Banks return	2.85			0.83		
Full EBA sample:						
equity return	1.43	1.61	3.08	2.06	1.71	2.93
exposure[3]	1.57	0.85	1.76	1.57	0.85	1.76
SNL subsample of EA countries:						
equity return	0.60	0.54	2.81	1.45	0.82	2.71
exposure[1]	12.96	10.79	12.89	12.96	10.79	12.89
Δ yield (10y)[2]	-0.23	-0.16	0.21	-0.04	-0.01	0.07
Δ SM [2]	1.81	2.39	2.26	1.05	0.95	1.51
EURO STOXX return	3.21			1.21		
EURO STOXX Banks return	1.28			1.54		
EBA subsample of EA countries:						
equity return	0.24	0.36	2.83	2.58	2.05	3.31
exposure[3]	2.34	1.87	1.75	2.34	1.87	1.75

[1] Exposure is defined as total sovereign exposure as % of total assets.

[2] Average over 28 EU countries/ 19 euro area countries. Bond yields excluding EE, CY, LV.

[3] Exposure is defined as exposure to EA sovereign bonds with 5- to 10-year maturity as % of total assets.

4.2.2 Results

Table 4 presents summary statistics for our data on stock price changes for the SNL and EBA samples, respectively.

Two notable features emerge from the table. First, individual banks' stock prices have increased, on average, both on 22 January and on 5 March. On 22 January the increase is equal to 1.4% for the EBA sample and 1.2% for the SNL sample. These averages, which are not value weighted, compare to a 2.8% increase in the STOXX Europe 600 Banks index. The second notable feature emerging from table 4 is that the banks' equity prices increased less than the overall stock market index. The STOXX Europe 600 went up by 3.4%. The difference is particularly large for euro area-based banks. The EURO STOXX Banks index increased by 1.3%, compared to a 3.2% increase in the total EURO STOXX. This suggests that concerns with the effect of the PSPP on banks' profitability might have been in the mind of stock market investors.

Tables 5 and 6 present the results of our regression equation, which in the most general form includes the following variables

$$\Delta P_{it} = \alpha + \beta_1 \cdot \Delta yld_{kt} + \beta_2 \cdot \Delta SM_{kt} + \beta_3 \cdot \text{EA bank} + \beta_4 \cdot \text{exposure}_{it_0} + \beta_5 \cdot \text{Shortfall}_{it_0} + \varepsilon_i \quad (1)$$

The dependent variable is represented by the change in the logarithm of the closing-price of individual banks' stocks. More precisely, for an announcement date t and bank i, the dependent variable is $\Delta P_{jt} \equiv \left[\ln\left(P_{t-1}^{close}\right) - \ln\left(P_{t-1}^{close}\right)\right] \cdot 100$.

The following explanatory variables are included in the regressions. (1) The change in 10-year sovereign bond yields: $\Delta yld_{kt} = yld_{k,t-1} - yld_{k,t-1}$, where k denotes the country where the bank is located. (2) The change in the national stock market index SM_{kt} of the country where the bank is located: $\Delta SM_{kt} = \left[\ln\left(SM_{t-1}^{close}\right) - \ln\left(SM_{t-1}^{close}\right)\right] \cdot 100$. (3) The share of sovereign bonds on each bank's balance sheet, denoted as exposure, measured at a point in time t_0 prior to the PSPP announcements. The point t_0 corresponds to end-2014 for the SNL database and to end-2013 for the EBA database. We adopt two different definitions of exposure. In the SNLdatabase, we have exposure_{it_0} = total sovereign bond holdings_{it_0}/ total $\text{assets}_{it_0} \cdot 100$, where the total sovereign bond holdings_{it_0} variable includes all bond holdings irrespective of the issuing sovereign. In the EBA database we have more refined information about the maturity and the issuer. We therefore work with exposure_{it_0} = EA sovereign bond holdings $(5\text{-}10\text{y})_{it_0}$/total $\text{assets}_{it_0} \cdot 100$, where EA sovereign bond holdings $(5\text{-}10\text{y})_{it_0}$ denotes exposure to sovereign bonds with remaining maturity between 5 and 10 years and issued by a euro area sovereign. (4) We also use a EA bank dummy, which is 1 if the bank is located in a euro area country. (5) Finally, when using EBA data, we can also construct a Shortfall $_{it_0}$ dummy, which is equal to 0 if the bank was considered undercapitalised in the comprehensive assessment and thus indicates whether the bank is well capitalised.

Our results based on the SNL and EBA databases are reported in Table 5 to 8, respectively. Tables 5 and 7 focus on bank equity price changes between 21 and 23 January 2015; Tables 6 and 8 concentrate on changes between 4 and 6 March 2015. The significance of all coefficients is computed using White robust t-statistics with degrees of freedom correction.

The first column in Table 5 includes only the constant and the country-specific regressors Δyld_{kt} and ΔSM_{kt}. All three regressors are statistically significant and positive. The regression explains 9% of the cross-sectional variation in banks' stock prices. Banks' stock prices increased on average when the PSPP programme was announced; the increase was larger for banks based in countries where the national equity price index increased more; however, a larger fall in the country's 10-year government bond yields was accompanied by a lower increase in banks' stock prices.

These findings suggest that the signalling channel was active for the PSPP announcement on 22 January. The announcement led to an improvement in expected future macroeconomic conditions, with positive repercussions on expected future discounted profits for all quoted companies, and specifically for quoted banks.

Table 5: Equity price reactions between January 21 and 23, 2015
SNL sample

	(1)	(2)	(3)
constant	2.5521***	2.086***	1.7368***
	(4.3814)	(3.8071)	(3.2107)
Δyield	15.6672***	9.124***	8.7575***
	(4.6094)	(2.8323)	(2.7549)
ΔSM	0.3914***	0.7964***	0.7673***
	(2.8819)	(3.9617)	(4.5419)
EA bank (d)		-2.233***	-2.5587***
		(-3.6466)	(-4.6897)
exposure			0.0563***
			(2.7259)
Adj. R^2	0.09	0.1861	0.2585
No. Obs.	150	150	120
	(White robust t-statistics)		

Table 6: Equity price reactions between 4 and 6 March 2015
SNL sample

	(1)	(2)	(3)
constant	0.5074	0.217	-0.4215
	(1.3946)	(0.3136)	(-0.3866)
Δyield	-4.9054	-2.255	4.2711
	(-1.0385)	(-0.2835)	(0.4258)
ΔSM	0.3752*	0.3	0.5937***
	(1.963)	(1.5511)	(3.0655)
EA bank (d)		0.6483	0.9845
		(0.6738)	(0.8073)
exposure			0.0289
			(1.0161)
Adj. R^2	0.0071	0.007	0.0152
No. Obs.	150	150	120
	(White robust t-statistics)		

The finding of a lower increase in bank equity prices, the larger the fall in long-term sovereign yields, is suggestive of an adverse effect on bank profitability. A flattening of the yield curve should, ceteris paribus, reduce bank profitability, because banks engage in maturity transformation. The finding is consistent with the results in English, Van den Heuvel and Zakrajsek (2012), which finds that US bank stock prices decline substantially following an unanticipated increase in the level of interest rates or a steepening of the yield curve.

The second column in Table 5 adds the euro area bank dummy to the regression. The dummy is strongly significant and negative. The other regressors also remain significant and the R^2 increases to 19%. We interpret also the euro area dummy as a reflection of the negative

impact of the flattening of the yield curve on banks' profitability. This effect is stronger for euro area banks, because their profits should be more closely affected by the slope of the euro area yield curve than profits of non-euro area banks. This interpretation is supported by the EBA data reported in Table 4, where more precise information on bond holdings is available. The table shows that the average exposure of European banks to euro area sovereign bonds with maturity between 5 and 10 years is equal to 1.6% (as a share of their total assets), while the average exposure of euro area banks is 2.3%. In turn, euro area yields are obviously more likely to be affected by large-scale purchases of euro area sovereign bonds.

Regression results including individual banks' exposure to sovereign bond yields are reported in the third column of Table 5. The point estimate is equal to 0.06, implying that, ceteris paribus, a bank holding 10% more sovereign bonds as a ratio of its total assets experienced a larger stock prices increases by 0.6%. Since 10% is one standard deviation in the cross-sectional distribution of sovereign bond holdings, this effect is non-negligible, as well as strongly significant. All other regressors also remain significant and the R^2 goes up further to 26%.

This result is consistent with the view that, by pushing up bond prices, the PSPP produced a "stealth recapitalisation" of leverage-constrained institutions, including banks (see Brunnermeier and Sannikov, 2013). The increased valuation of bond prices can thus be expected to foster an improvement in credit conditions and to boost economic activity. Brunnermeier and Sannikov (2013) also argue that stealth recapitalisation can be expected to help more those institutions that hold a larger share of long-term bonds. Our results are consistent with this view, since stock prices increase more for banks with larger sovereign bonds exposure.

Brunnermeier and Sannikov (2013) also suggests that, ceteris paribus, more severely leveraged banks should benefit less from the PSPP. We explore this conjecture in more detail in Tables 7 and 8 with the EBA database, which includes information on banks' capital levels before the programme.

Table 6 shows that most regression coefficients are not significant explanatory variables of equity price changes between 4 and 6 March. In many cases, however, the sign of point the estimates is consistent with that observed between 21 and 23 January.

Columns 1-3 in Table 7 display the regression results for the EBA database. In this case, we can focus on sovereign bond holdings of a specific maturity. This is arguably important, since large holdings of short-term sovereign bonds should not be affected much by the PSPP. The reason is that shorter term yields were already close to zero before the PSPP was announced. We therefore select the 5/10-year maturity bracket, which is also more consistent with the 10-year yield change that we include as control in the regression.

The results for the EBA sample are largely consistent with those based on the SNL sample. All coefficients have similar sign and magnitude. They are also statistically significant with the exception of the bond exposure coefficient, which is positive, but insignificant. The discrepancy between the two databases could be due to a number of reasons. First and foremost, the smaller

statistical significance could be due to the fact that the EBA sample is much smaller–it includes about 1/3 of the banks in the SNL sample. A second possibility is that the SNL information is more up-do-date, thus closer to markets' information set when pricing the effects of the PSPP announcement on equity prices.

Finally, column 4 in Table 7 includes the capital shortfall dummy in the regression. The dummy is positive, but statistically insignificant.

To summarize, we have shown that the reaction of individual banks' equity prices to the PSPP announcement are partly explained by the share of the bank balance sheet invested in sovereign bonds: the larger this share, the more banks benefited from the PSPP announcement. This effect remains present after controlling for the negative effects of the PSPP on banks' stock prices due to the likely reduction in their interest rate margins, and for its positive effects through signalling of lower expected future policy interest rates.

The evidence of a link between banks' holdings of sovereign bonds and the reaction of their equity price to the PSPP announcement is supportive of the asset valuation channel. Ceteris paribus, banks with a larger asset share in sovereign bonds are expected to enjoy higher expected discounted future profits after the programme. Their reduced leverage can be expected to lead to an expansion in lending and thus support the economic recovery.

4.3 Persistence of the asset-price effects

The asset-purchase programme can influence broader economic developments only if its financial market impact is persistent. In this section, we present evidence on the dynamic effect of the APP on sovereign and private yields, the exchange rate and various stock market indices. We show that these effects are indeed quite persistent. More specifically, their persistence is comparable to that of standard monetary policy impulses, which have been shown to have significant impact on inflation and economic activity.

The evidence in this section is based on a daily vector autoregression (VAR) of financial variables, where asset-purchase shocks and monetary policy shocks are identified using external instruments (Stock and Watson, 2012; Mertens and Ravn, 2013).[11] The daily VAR is estimated on data from 2 January 2013 to 30 December 2015, i.e. the period starting after the amelioration of acute phase of the euro area sovereign debt crisis. The baseline model includes the 5-year synthetic euro area AAA and all-euro-area sovereign yields, the Merrill Lynch AAA and BBB corporate bond yield indices, the EUR/USD exchange rate and the Stoxx 600 euro area stock market index. The exchange rate and the stock market index are included in the VAR as first differences of their log levels, while yields are included in levels. The VAR is estimated with one lag. Further relevant variables are added one-by-one to the baseline 6-variable VAR and estimated in a 7-variable system. These additional variables include the 10-year AAA sovereign bond yield, a stock market index of euro area banks, yields on euro area bank bonds (Gilchrist and Mojon, 2014).

[11] Results in this section are based on ongoing work in Jarocinski and Karadi (2016).

Table 7: Equity price reactions between 21 and 23 January 2015
EBA sample

	(1)	(2)	(3)	(4)
constant	4.0805**	1.512	1.2512	-0.0481
	(2.6233)	(1.1449)	(0.8388)	(-0.0281)
Δyield	18.0779***	8.2205*	9.0655**	6.6658*
	(2.9935)	(1.8491)	(2.1523)	(1.7438)
ΔSM	0.0147	1.773**	1.9578**	1.6934**
	(0.0196)	(2.553)	(2.2477)	(2.6812)
EA bank (d)		-4.6503***	-5.365***	-4.249***
		(-5.7227)	(-3.7109)	(-5.5096)
exposure			0.265	
			(0.6694)	
Shortfall (d)				1.5243
				(1.6029)
Adj. R^2	0.0693	0.3241	0.3243	0.3436
No. Obs.	51	51	51	51
	(White robust t-statistics)			

Table 8: Equity price reactions between 4 and 6 March 2015
EBA sample

	(1)	(2)	(3)	(4)
constant	1.0425*	0.7179	0.7263	2.857
	(2.0046)	(1.2908)	(1.3148)	(1.2956)
Δyield	-4.6478	-0.8825	-0.7829	4.925
	(-0.9524)	(-0.0756)	(-0.0652)	(0.3071)
ΔSM	0.9683***	0.8518**	0.8487**	0.7121
	(3.8375)	(2.4341)	(2.3283)	(1.5227)
EA bank (d)		0.7706	0.9242	0.7211
		(0.4661)	(0.4488)	(0.4966)
exposure			-0.0656	
			(-0.272)	
Shortfall (d)				-2.2799
				(-0.9201)
Adj. R^2	0.0524	0.0407	0.0209	0.0966
No. Obs.	51	51	51	51
	(White robust t-statistics)			

As instruments, the authors use intraday responses of the 5-year German government bond to policy announcements. The surprise APP announcement is measured as the change in this yield within a 90-minute window initiated 10 minutes before the start of an APP related press conference or speech and ending one hour and 20 minutes after (the regular ECB press conferences last exactly one hour; the methodology implicitly assumes that the speeches also take so long). The 25 announcements related to the APP are the events taking place between

June 2014 and December 2015 based on Altavilla, Carboni and Motto (2015) and extended to include all press conferences between March 2015 (the cutoff date of that paper) and December 2015 and the President's speech at the European Parliament on 12 November 2015. The authors identify standard monetary policy surprises as changes in the 5-year German bund within a 30-minute window around 34 regular press releases on key ECB policy rates between January 2013 and December 2015. The observation window starts 10 minutes before the press release and ends 20 minutes after. F-statistics of the first stage regressions regressing the instruments on the residual of the 5-year AAA sovereign bond yield are sufficiently high so that instruments are valid (i.e. not weak).

Figure 3 presents the results for an APP and a standard monetary policy shock. The impact effect of both shocks on a 10-year AAA sovereign bond is normalized to -15 basis points, an impact consistent with that observed around the 22 January 2015 APP announcement. The black solid lines show the average dynamic impact of an unexpected APP-related news. The dashed black lines around it show 95 percent confidence bands.[12]

The results show that the financial market effects of the APP news are persistent: the half-life of the impact on the 10-year rate is more than one year. The shock also persistently reduces the bond yields of banks and non-financial corporations, depreciates the exchange rate and raises the valuation of the stock market in general and of bank stocks in particular.

The impacts observed as a response to an APP shock are broadly comparable to a standard interest rate shock. The 10-year yield after an interest rate shock tends to be somewhat more persistent, and leads to larger impact on non-financial corporation and bank bond yields. These results are robust to a backward extension of the sample until 2004, so as to include 246 regular press statements.[13]

4.4 The impact of the APP on expectations

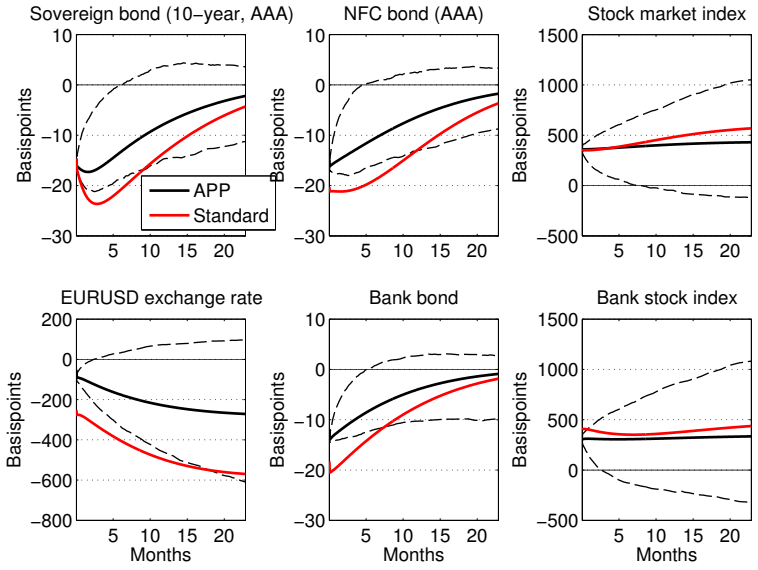
In this section, we investigate how the private sector adjusted its expectations on future monetary policy when the APP was announced. We look at the reaction of both the average of individual forecasts and the cross-section dispersion of these individual forecasts, i.e. the extent of disagreement among forecasters. More precisely, we measure disagreement as the interquantile range in the distribution of individual forecasts for a given variable, horizon and date.

Our results provide suggestive evidence for both the signalling channel and the reanchoring channel at the time of the APP announcement. We highlight two main results.

1. Based on survey measures of 1-year and 2-year ahead forecasts, we first document that the APP announcement was followed by expectations of lower future short-term interest rate, and higher inflation and output growth rates. This evidence is consistent with the signalling channel, which suggests that quantitative easing policies create expectations of

[12] The confidence bands are calculated using wild bootstrap.
[13] These results are available from the authors upon request

Figure 3: Dynamic asset price impact of an APP and a standard monetary policy shock, daily VAR, 2013-2015



The figure shows the response of key financial variables to an APP and a standard monetary policy shock.

an easier monetary policy stance in the future, hence a faster recovery and upward price pressure. To corroborate this evidence, we also look at the evolution of disagreement amongst forecasters. The signalling channel would suggest that disagreement should be reduced, due to the central banks signal of a more expansionary future policy stance. We show that disagreement regarding future policy rates did fall markedly after the APP announcement. Disagreement regarding future inflation and output growth, however, remained broadly unchanged.

2. We also show that long-run inflation expectations were revised towards levels closer to 2 percent after the APP announcement, thus reverting the downward trend experienced since end-2012. We present suggestive evidence that these revisions were positively correlated with changes in short-term inflation forecasts, and negatively correlated with expected movements in short-term interest rates. This evidence is consistent with the reanchoring channel defined in Section 2.

4.4.1 Data

We rely on two sources of information to measure the reaction of macroeconomic expectations to the program.

The first one is the ECB Survey of Professional Forecasters. This is a quarterly survey which runs since 1999Q1 and collects forecasts of various institutions for (among others) the euro area inflation, GDP growth and the ECB policy rate at various forecast horizons. More

specifically, the survey collects forecasts for the year-on-year HICP inflation and GDP growth rates one year, two years and five years ahead. Forecasters are also asked to report their forecasts of the interest rate on the ECB main refinancing operations for the next 4 quarters as well as for next calendar year and the one after the next.

The second source are Overnight Index Swaps (OIS) that we use to derive forward 1-year interest rates expected for horizons between 1 year and 10 years ahead. The original series are observed at a daily frequency. To make them consistent with the SPF, we converted them to a quarterly frequency by selecting for each quarter the deadline date at which professional forecasters were asked to send their answers to the ECB.

We work with a 1999Q1-2015Q3 sample. The event we are particularly interested in is the announcement of the APP program on January 22, 2015. The closest survey round is 2015Q1 which was conducted between January 7 and January 13, that is just before the Governing Council during which the program was decided. The 2015Q2 round of the survey was conducted between March 31 and April 7. We associate the change in our various measures of expectations between these two rounds of 2015Q1 and 2015Q2 as mainly reflecting the impact of the program on the expectations of professionals.

4.4.2 The impact on expected future policy, inflation and GDP growth rates

Figures 4a, 4c and 4d respectively display the evolution of the average SPF forecasts for the ECB's policy rate, the euro area inflation rate and the euro area GDP growth rate. The vertical line marks the date of the survey round of 2015Q1, which happened right before the announcement of the program.[14] These charts reveal that, after the program was announced, the average expectation of future policy rates decreased for all forecast horizons except the very short ones which were already very close to zero since September 2014. More precisely, after the announcement of the APP and between 2015Q1 and 2015Q3, policy rate forecasts declined from 11 to 6bps for 2016 and from 43 to 31bps for 2017. So the program signalled lower policy rates to come up until 2017.[15] Over the same period, expectations of future inflation and growth rates increased respectively by 45bps and 55bps for the 1 year ahead forecasts. Long-term inflation forecasts which had declined by roughly 15bps over 2014 increased by 9bps between 2015Q1 and 2015Q3.

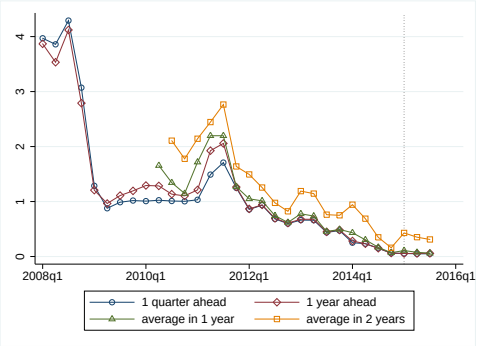
These developments are consistent with an active signalling channel for the ECBs asset purchase programme. Accordingly the APP was interpreted as the signal of a lower path for future policy interest rates and, as a result, higher future growth and inflation.

[14] See the above Data section for more details.

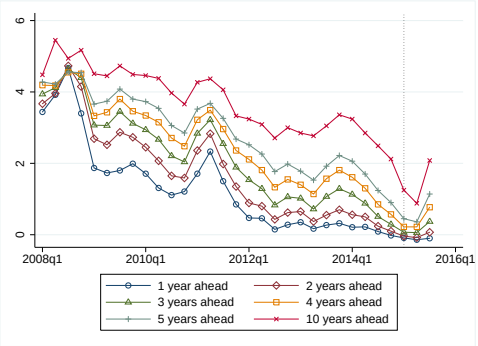
[15] Similar observations can be made if one looks at markets' expectations of short-term interest rates derived from forward OIS contracts, for horizons going from 1y to 10y as is illustrated in Figure 4b. This evidence of a signalling impact is consistent with results reported in Altavilla et al. (2015) that short-term forward rates derived from OIS declined on the day of the program. It is also comparable to results derived from the US experience. **?** illustrate that the unconventional policies of the Fed such as quantitative easing lowered expected short term interest rates.

Figure 4: Expectations of future interest rate, inflation and GDP growth

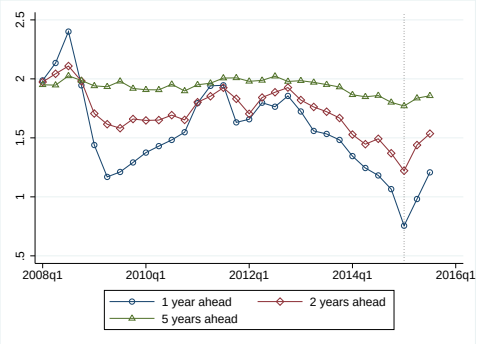
(a) Policy rate forecasts from SPF



(b) Forward 1-year interest rates from OIS



(c) Inflation forecasts from SPF



(d) GDP growth forecasts from SPF

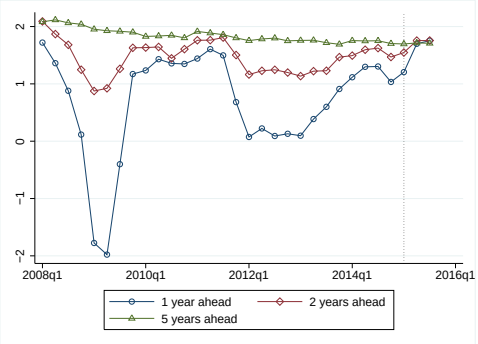
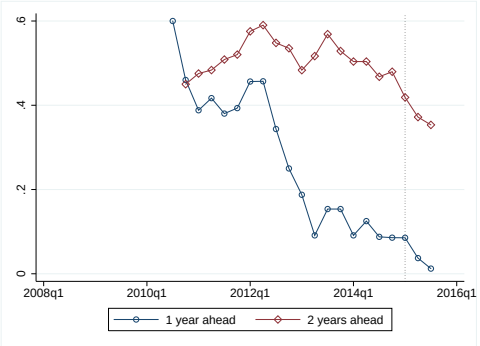
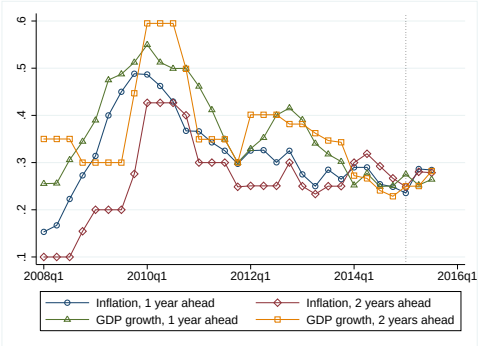


Figure 5: Disagreement about future interest rate, inflation and GDP growth

(a) Interest rates



(b) Inflation & GDP growth



Consistently with the signalling channel, one would also expect a reduction in the cross-sectional dispersion of forecasts across different forecasters. Figure 5a displays the evolution of disagreement about future ECB's main policy rate and Figure 5b reports the evolution of disagreement for inflation and GDP growth in the euro area. Three main comments can be made. First, the two figures reveal that, in addition to its impact on the level of expectations of macroeconomic variables, the APP has also reduced the dispersion of forecasts about euro area forecasts of future short-term interest rates. The APP reinforced the private agents' beliefs that the policy rate would stay close to zero up until the end of 2016. Second, Figure 5a also illustrates that the level of coordination of opinions reached when the APP started to be implemented was never observed before, neither when the EA launched the 3 year Long Term Refinancing Operations (On December 14 2011), nor when the ECB engaged into forward guidance (on July 4, 2013) or committed to full liquidity allotment until the end of 2016 (on June 5, 2014). So there is a decline that is specific to the announcement of the program. Third, as Figure 5b reveals, at the time when the APP was launched, disagreement about inflation and GDP growth has not declined significantly, but it has continued hovering around the levels of 2015.

The joint evolution of disagreement of future interest rates, inflation and growth is surprising. Indeed, in normal times, future inflation and demand should determine future interest rates through the policy reaction function of the central bank (e.g. a classical Taylor rule).[16] How can it be that, exactly at the time of explicit forward guidance, forecasters agreed on future short-term interest rates but disagreed on future macroeconomic outcomes? As Andrade et al. (2015) emphasize, this situation can happen when agents understand differently the same path of future policy rates.

[16] Andrade et al. (2013) show that, over the past 30 years, and for a large range of forecasting horizons, disagreement about future short-term interest rate can be explained by forecasters agreeing on the Fed's reaction function but disagreeing about fundamentals, namely future short-term interest rates, future inflation and future growth rates.

Indeed, there are two macroeconomic scenarios that are consistent with a policy signalling that interest rates will stay at zero for an extended period of time implied by the flattening of the yield curve induced by the APP. Either agents view the interest rate path as being consistent with a more accommodative monetary policy stance that will last beyond the point when the economy exited the lower bond (more accommodation). They therefore have relatively optimistic forecasts of future macroeconomic conditions. Or agents believe the central bank views the interest rate path as consistent with a monetary policy constrained to be at the ZLB for a long period of time and therefore have bleak forecasts of future macroeconomic conditions (longer trap). Since future fundamentals are not observed, private agents have no clear way to discriminate between these two macroeconomic scenarios.[17]

A question is therefore to know which interpretation of the APP prevailed in the mindset of agents: more accommodation or longer trap?

4.4.3 What Is the Stance Private Agents Associated to the APP?

More accommodation would correspond to future negative deviations from the usual policy rule, whereas longer trap would imply future positive deviation from the usual policy rule. We therefore infer the dominant interpretation of the impact of the APP by estimating the average deviation from the usual policy rule that agents had in mind when the programme was announced.

In a first step, we use the individual forecasts of short term interest rates, inflation rates and GDP growth rates to estimate a pre-crisis Taylor rule. Namely, we estimate the following panel regression over a 1999Q1-2007Q4 sample:

$$r_{it,t+h} = \rho r_{it,t+h-1} + (1-\rho)\left[\overline{r}_i + \alpha_\pi(\pi_{it,t+h} - \overline{\pi}_{it}) + \alpha_y(\Delta y_{it,t+h} - \Delta\overline{y}_{it})\right] + \epsilon_{it,t+h},$$

with $r_{it,t+h}$ individual i's forecast of short-term interest rate for date $t+h$, $\pi_{it,t+h}$ individual's i forecast of inflation rate for date $t+h$, $\Delta y_{it,t+h}$ individual's i forecast of GDP growth rate for date $t+h$, $\overline{r}_i$: individual i's perceived average natural rate, $\overline{\pi}_{it}$ individual's i 5-year inflation forecast and $\Delta\overline{y}_{it}$ individual's i 5-year GDP growth forecast.

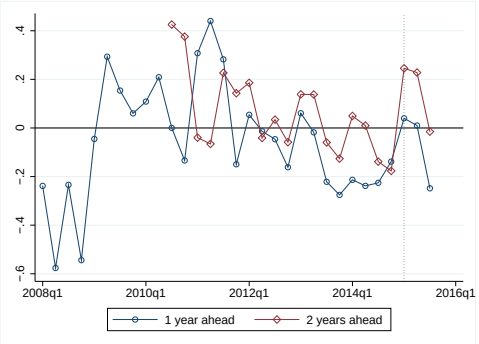
In a second step, we use the estimated parameters $\widehat{\rho}$, $\widehat{\alpha}_\pi$ and $\widehat{\alpha}_y$ together with forecaster's i forecasts of future inflation and GDP growth observed during the crisis period to get the expected short term interest rate that would be observed if forecasters had relied on the pre-crisis Taylor rule:

$$\widehat{r}_{it,t+h} = \rho r_{it,t+h-1} + (1-\rho)\left[\overline{r}_t + \widehat{\alpha}_\pi(\pi_{it,t+h} - \overline{\pi}_{it,t}) + \widehat{\alpha}_y(\Delta y_{it,t+h} - \Delta\overline{y}_{it,t})\right],$$

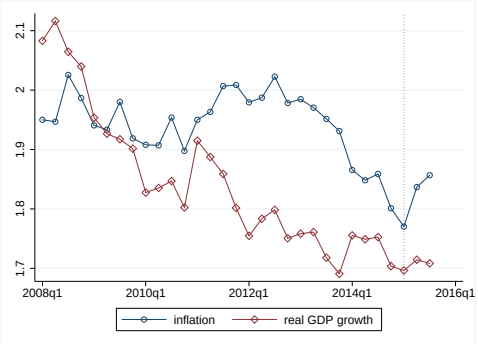
[17] One could consider that the policy could convey the information. However, as Andrade et al. (2015) show, when private agents have different views on the commitment ability of the central bank to fulfil its promise of more accommodative policy in the future, the policy is ambiguous on the end of the trap so that, in equilibrium, agents agree on the path of nominal interest rates, without agreeing on the length of the trap.

Figure 6: Channels of transmission of the APP

(a) Future stance



(b) Reanchoring



where $\overline{r}_t$ is the target interest-rate of the central bank. It is defined here as the short-term interest rate that would be observed had the economy converged to the target level of inflation and to potential output growth. We do not observe individual forecasts of this variable. We proxy it with a measure of short term interest rate which, conditional on the current macroeconomic outlook, is expected to be observed far in the future. More precisely we rely on the 1-year rate interest rate expected in 10 years from forward OIS rates. In sum, the estimate $\widehat{r}_{it,t+h}$ gives us the future policy rate that would be consistent with individual i's inflation and GDP growth rate forecasts, had the ECB stuck to its normal times reaction function. We then get an estimate of individual i's forecasted deviation from the normal times / pre-crisis reaction function of the ECB as the difference $\widehat{\epsilon}_{it,t+h} = r_{it,t+h} - \widehat{r}_{it,t+h}$.

Figure 6a illustrates the results. It suggests that expectations of future monetary stance were going into the direction of less accommodation to come since the second half of 2014. However, such expectations have been reversed after 2015Q1 and the beginning of the APP and the program insured that private agents kept expecting future monetary policy accommodation compared to normal times.

4.4.4 The impact of the APP on long-term inflation expectations

As Figure 6b reveals, a striking feature of the APP is that long-run inflation expectations, which were trending downward since the end of 2012, increased by 9bps between 2015Q1 and 2015Q3 (from 1.77 to 1.86%), hence getting closer to the quantitative definition of price stability of the Eurosystem. What was responsible for this change?

Results presented in Table 9 provide a tentative answer. Columns (1) and (2) suggest that revisions in relatively short-term inflation expectations are positively correlated with revisions in long-term ones. In other words, when short-term expectations increase, long-term expectations also tend to move upwards, albeit by a much smaller amount. Moreover, as columns (3) and (4) reveal, changes in future short-term interest rates have a specific impact on long-term inflation expectation that comes in addition to changes in short-term inflation

Table 9: Signalling and reanchoring

Dependent variable: Revisions in LT inflation forecasts				
	(1)	**(2)**	**(3)**	**(4)**
Revisions in ST inflation forecasts	0.04**	0.07***	0.13***	0.12***
	2.12	3.20	5.06	2.54
Changes in expected future monetary policy			-0.03*	-0.01
			-1.68	-0.42
Past LT inflation forecasts	-0.20***	-0.13*	-0.46***	-0.10
	-3.05	-1.97	-4.01	-1.03
Constant	0.39***	0.26**	0.90***	0.19
	3.10	2.00	4.07	1.03
R2	0.22	0.23	0.53	0.25

Revisions in long-term (LT) inflation forecasts are changes in the end of the year inflation forecast 5 years from now from the ECB SPF. The past LT inflation forecast is measured by the end of the year inflation forecast 5 years from now observed in the ECB SPF survey round of the previous quarter. The change in the expected interest policy is the revision in the end of next year main refinancing operations interest rate forecasts observe compared to one observed quarter ago as observed in the ECB SPF. Columns (1) & (3) revisions in short-term inflation forecasts are measured as the difference between 1-year inflation forecasts and 2-year inflation forecasts observed one year ago; in columns (2) & (4) these are the change in the 1-year ahead inflation forecasts compared to one quarter ago. The sample covers the 1999Q1-2015Q3 period. Standard errors are obtained via a HAC Newey-West procedure. ***, **, * indicate significance at resp. the 1%, 5% and 10% level.

expectations: expectations of a future monetary accommodation have an impact on inflation expectations that goes beyond the short run. These results are consistent with the reanchoring channel, i.e. the idea that private agents are uncertain about the long-run inflation target, as emphasized in e.g. Gürkaynak, Sack and Swanson (2005), and try to learn from current realizations what will have permanent or very persistent effects, as emphasized in Andrade et al. (2013).

Between 2015Q1 and 2015Q3, one year ahead inflation forecasts increased by 45bps (from 0.76 to 1.21%) while expectations of future short interest rates for 2016 decreased by 5bps (from 11 to 6bps). Given these changes, the regression results of Table 9 (Column 4) would imply a predicted increase of 4.55bps in long term inflation forecasts, mostly stemming from the revisions in short-term inflation expectations observed during that period.

5 Macroeconomic assessment

We assess the macroeconomic impact of the APP in the euro area through the lens of a stylized macroeconomic model. The framework we adopt (Gertler and Karadi, 2013) extends standard monetary macroeconomic models (see e.g. Christiano, Eichenbaum and Evans, 2005; Smets and Wouters, 2007) with financial intermediaries that face funding constraints. Asset purchases by the central bank raise inflation and stimulate economic activity, because they

ease aggregate credit conditions and help to reanchor inflation expectations. We calibrate the model to capture relevant observations of the euro area economy, and use it to simulate a stylized economic environment that forms the backdrop to recent asset-purchase policies. We then assess the macroeconomic impact of the APP policy as announced in January 2015, and show how modifying some of its key characteristics might further enhance its effectiveness.

5.1 The framework

The model we use[18] extends the standard framework with banks that face market-imposed leverage constraints. As a result, the balance sheet position of banks actively influences the price and the availability of credit in the economy.

Large-scale asset purchases by the central bank exchange longer-term, moderately risky private and public assets to overnight, safe central bank deposits. This exchange mitigates the riskiness of banks' portfolios. This allows them to raise external funds, and extend new credit at lower required yields to the public and private sectors, in line with evidence shown in Section 4.1. Furthermore, in a positive financial feedback loop, the improving asset valuations raise banks' equity, induces capital relief – in line with evidence shown in Section 4.2 – and further eases their funding constraints. The more 'risk' the central bank eliminates from private portfolios, the larger impact its policy has. When devising its policy, the central bank needs to balance the welfare improvement caused by macroeconomic stabilization with the potential costs of holding risky assets in its portfolio.

The announcement of the expanded asset purchase programme substantially increased long-term inflation expectations as we showed in Section 4.4. We capture this reanchoring channel of the policy by assuming that the private sector is uncertain about the central bank's inflation objective (Gürkaynak, Sack and Swanson, 2005), and the asset purchase programme offers a credible mean for the central bank to guide expectations even when the interest rate is stuck at its effective lower bound. Private agents, in our framework, assume that the central bank's inflation target is time varying, even though, unbeknown to them, the actual inflation target

[18] For details of the model, please see Gertler and Karadi (2013). We modify the original framework in some important respects. First, we assume that the interest rate rule responds (i) to the inflation target, (ii) to the deviation of the inflation rate from the target, and to the quarterly change in the (iii) inflation rate and (iv) output, as shown formally in the equation below. The rule captures the past conduct of euro area monetary policy better than a conventional Taylor rule (see Christoffel, Coenen and Warne, 2008).

$$i_t^* = \rho_i i_{t-1} + (1-\rho_i)\left[\pi_t^* + \kappa_\pi(\pi_t - \pi_t^*) + \kappa_y y_t\right] + \kappa_{\Delta\pi}(\pi_t - \pi_{t-1}) + \kappa_{\Delta y}(y_t - y_{t-1}) + \varepsilon_t$$

We also assume that as long as the rule requires a policy rate below its effective lower bound, the central bank keeps it at its lower bound (zero in our stylized framework, $i_t = \max(0, i_t^*)$). The model, therefore, disregards the signalling channel of the asset purchase policy. On the contrary, it assumes that without additional forward guidance the policy might actually shorten the period until the date the interest rate is expected to lift off from its lower bound by improving the inflation and output outlook.

Second, we introduce uncertainty and learning about the central bank's inflation target in the spirit of Gürkaynak, Sack and Swanson (2005) to capture potential deanchoring of inflation expectations. Third, we introduce sluggish wage adjustment to the model in line with Erceg, Henderson and Levin (2000) to increase its realism.

happens to stay constant throughout our exercises.[19] Agents update their perceived inflation target in case the observed inflation rate, output, the interest rate or the asset purchase policy deviate from their expectations.[20]

5.2 Calibration

We calibrate the parameters of our model to capture key euro area stylized facts.

The tightness of the aggregate credit conditions implicitly determines the potential credit-easing effect the asset-purchase programme. We use observations on the average long-term level of interest rate premia of private and public assets over the short-term riskless policy rate to calibrate the extent of overall and asset-specific funding constraints.[21] The leverage of banks influences how much changes in their asset valuations impact their market capitalization, thereby it determines the strength of the financial feedback loop. We calibrate the leverage of our financially constrained agents to 6, which is the average leverage of financial institutions and non-financial corporations in the euro area.[22]

[19]The constant actual inflation objective and the time-varying perceived objective means that the expected and the actual interest rates can differ even along the path of dynamic responses to a perfectly foreseen policy shock. We assume that agents attribute this deviation to a contemporaneous temporary monetary policy shock and form their predictions accordingly. As the predictions influence the behavior of other endogenous variables as well, the fixed-point algorithm we use solves for a perceived monetary policy shock that is consistent with the actual outcomes.

[20]In particular, we assume that the perceived interest rate target (π^{*p}) follows a process of

$$\pi^{*p}_{t+1} = \rho_{\pi^{*p}}\pi^{*p}_t - \kappa\left\{i_t - i^e_t - \varsigma(\Psi_t - \Psi^e_t) - \left[(1-\rho_i)\kappa_\pi + \kappa_{\Delta\pi}\right](\pi_t - \pi^e_t) - \left[(1-\rho_i)\kappa_y + \kappa_{\Delta y}\right](y_t - y^e_t)\right\},$$

where $\rho_{\pi^{*p}}$ is the (close to unity) persistence of shocks to the perceived inflation target, Ψ_t is a measure of the stock of assets held by the central bank. Superscript e reflects private sector expectations for a variable in time t formed in $t-1$. The updating rule is motivated by learning with a constant (κ) gain parameter. Unobserved temporary monetary policy shocks hamper the market participants' ability to infer the actual inflation target. The best they can do is to form expectations based on observed policy responses to economic outcomes. Away from the interest rate lower bound, interest rate responses to inflation and activity are informative, and agents keep their long-term inflation expectations anchored around the constant target rate. If the interest rate is stuck at its lower bound, then interest rate observations stay uninformative about the long-term inflation target. Asset purchase policy is a substitute, however, and we assume that agents turn their attention towards it to learn about the central bank's target. If low inflation rates are not followed by extended asset purchases, for example, the public would conclude that the central bank's long-term target has declined and it would lead to a deanchoring of their long-term inflation expectations. New purchases, on the contrary, help to reanchor long-term inflation expectations. The parameter ς measures the relative impact on the perceived inflation-target of surprise asset purchases relative to an interest rate surprise.

[21]In particular, we calibrate the private credit spread to match the average spread (2.45 percent) between the euro area long-term composite cost of borrowing indicator and the overnight Eonia rate between January 2003 and September 2015. The spread of the public assets are measured by the difference between the euro area 10-year yield and the Eonia rate between January 2003 and September 2015 (2.1 percent).

[22]The data uses monetary and other financial institution and NFC assets over equity weighted by their relative assets between 1999Q1 and 2014Q2 based on euro area sectoral accounts. We include the leverage of non-financial corporations because in practice both banks and firms hold leveraged positions. In our model, we do not allow firms to lever up, so we assign the average composite leverage to the financial intermediaries.

We calibrate the learning rule about the ECB's inflation objective to roughly capture the behavior of long-term inflation expectations around the introduction of the extended APP.[23]

- In the months prior to the introduction of the policy, long-term inflation expectations declined by approximately 15 basis points.[24] This deanchoring of inflation expectations helps us to pin down the impact of inflation surprises on the perceived target.[25]

- We assume that an interest rate surprise has the same quantitative impact on the perceived inflation objective as an equivalent asset purchase policy. We will find that the APP is comparable to a monetary policy shock of -1.1 percentage point, so we set the learning parameters in a way that such interest rate surprise has the same impact as the APP.[26]

- With these calibrations, the impact of the APP programme on the perceived inflation objective turns out to be around 9 basis points on impact. This is the magnitude of the response of market-based long-term inflation expectations reflected in market prices[27] on the day of the announcement of the program, and it is also in line with the change in the long-term inflation expectations of professional forecasters.[28] It is interesting to note that this requires a minor (less than 0.8 basis points) direct impact of the baseline asset purchase program on the perceived inflation objective. This direct impact gets amplified by more than an order of magnitude through two main channels. First, the policy raises inflation by easing lending conditions, which raises the perceived inflation objective indirectly through generating inflation surprises. Second, the higher perceived objective postpones the expected date of lift-off of the interest rate from its lower bound and also lowers the expected path of the policy rate after lift-off. The more accommodative expected policy raises actual inflation further through forward looking price-setting decisions.

Standard model parameters are taken from the New Area-Wide Model (NAWM), which is an open-economy macroeconomic model estimated on euro area data and used regularly

[23] We set the persistence of the shocks to the perceived inflation objective to $\rho_{\pi^{*p}} = 0.99$. This implies that the surprises have very persistent impact on the perceived target, but the impact is not permanent, so the system converges back to its original steady state.

[24] The survey of professional forecasters found that the average forecast for the five year ahead inflation rate decreased from 1.93 in 2013Q4 to 1.77 in 2015Q1 before the announcement of the APP programme.

[25] A learning gain parameter $\kappa = 0.062$ is in line with these observations. The same parameter determines the influence of the interest rate surprise on long-term inflation expectations. This is lower than a similar coefficient calibrated on US data (Gürkaynak, Sack and Swanson, 2005, 0.1) in line with the fact that the European Central Bank follows a transparent, and inflation-oriented policy. Such policy has been shown to anchor long-term inflation objectives tightly (Gürkaynak, Levin and Swanson, 2010).

[26] This implies a relative gain coefficient of $\varsigma = 0.068$.

[27] In particular, 5 and 10 year ahead inflation swaps.

[28] The SPF 5-year-ahead inflation forecasts increased from 1.77 percent in 2015Q1 to 1.86 percent by 2015Q3.

within the European Central Bank for forecasting and policy analysis (Christoffel, Coenen and Warne, 2008).[29]

5.3 Results

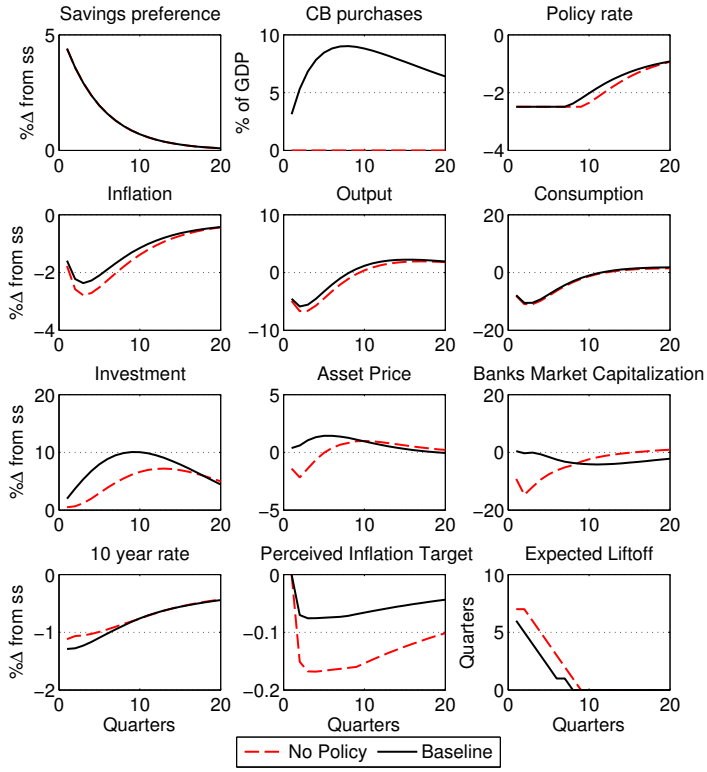
5.3.1 Macroeconomic impact of asset purchases

The introduction of the APP was preceded by a deteriorating economic outlook, persistently low inflation rates, deanchoring inflation expectations, low long-term yields, and the policy rate stuck at its lower bound. We capture key features of this environment in our framework by a persistent fall in demand caused by an unexpected increase in the households' 'preference for savings'. The shock captures unmodelled factors that induce households to postpone their consumption (like debt overhang or elevated precautionary savings caused by higher uncertainty). The red dashed line on Figure 7 shows the dynamic response of key macroeconomic variables to the shock. The shock mitigates consumption demand, which worsens economic outlook, reduces inflation and lowers asset prices. Without an asset purchase programme, the shock would have reduced the inflation rate by more than 2 percent, the output by around 7 percent. This brings the policy rate to its effective lower bound (zero in this stylized example), so monetary policy can not stabilize the economy using conventional instruments. In particular, the interest rate would have stayed stuck at its lower bound for more than 2 years. Excess savings generate a downward pressure on long-term sovereign yields, the ten-year government bond rate would have dropped by more than 100 basis points. If financial markets were frictionless, high savings would generate a investment boom, which would mitigate the negative impact on aggregate demand. Here, in contrast, lower asset prices reduce the market capitalization of financial intermediaries. This hampers their ability to raise external funds and channel savings towards investment. Therefore, aggregate lending declines and expected loan spreads increase, which keep investment from increasing at the onset of the demand shock.

Deanchoring inflation expectations contribute to the deteriorating outlook. The shock gradually lowers the perceived inflation target by around 15 basis points. As a result, inflation rates stay persistently below the central bank's medium-term inflation objective, because forward-looking price setters expect a tighter policy after the interest rate lifts off from its lower bound. Low inflation rates, furthermore, raise current real interest rates and further mitigate aggregate demand. The deteriorating outlook endogenously postpones the date the agents expects the policy rate to lift-off from the lower bound. Initially, agents expect the lower bound to bind for 7 quarters. As the persistent shock leads them to lower their perceived inflation target and even more their inflation expectations, 7 quarters later they still expect the lower bound to bind for a further 2 quarters. Eventually the interest rate stays at its lower bound for 9 quarters.

[29] Please see the calibrated parameters in Appendix A. The current version of the NAWM is estimated over the sample of 1985Q1-2011Q4 and explains the behavior of 18 different macroeconomic variables.

Figure 7: A stylized demand shock and the asset purchase program



The figure shows the response of key economic variables to a stylized savings shock, partly counteracted by an asset purchase program (baseline) and compares it to the counterfactual behavior of the economy in case of no policy response.

The introduction of the APP helps the European Central Bank to guide inflation towards its medium-term inflation objective. We capture the programme in a stylized fashion. The central bank purchases both private and public assets in a fixed 29-71 percent proportions. To account for both the quantity and the average maturity of the purchases, we measure the stock of purchased assets in 'ten-year equivalents.'[30] At its peak, the purchased assets reach 11.3 percent of 2014 euro area GDP. The average maturity of sovereign bonds is 9 years, and the maturity of covered bonds is 5.3 years, so the weighted maturity of the programme is 8 years. Consequently, the programme reaches around 9 percent of GDP in ten-year equivalents. The central bank's holdings of purchased assets follow a hump-shaped pattern increasing dynamically in the first two years, stay fairly constant in the following two years and then they gradually approach zero as the assets mature.[31]

[30] We obtain this measure by multiplying the purchases with the maturity and divide them by 10. The measure assumes that the 'riskiness' of assets increases linearly with maturity, i.e. an asset with 10-year maturity is twice as risky as an asset with 5-year maturity.

[31] In particular, the programme is modelled as a second-order autoregressive shock with the AR(1) coefficient of 1.7 and an AR(2) coefficient of -0.71.

The solid black line on Figure 7 shows the baseline outcome of our demand shock with an active asset purchase policy response, and Figure 8 plots the impact of the programme relative to the no policy outcome. Overall, the APP increases inflation gradually by around 40 basis points and output by around 1.1 percent reaching their peak in around 2 years. These effects are higher, but of a comparable magnitude to improvements in 2 year ahead inflation and output expectations measured by the Survey of Professional Forecasters.[32]. The policy would also reduce the 10-year sovereign yields and private corporate bond rates by around 20 basis points. The macroeconomic impact of the policy would be comparable to a standard monetary policy shock of -1.1 percentage point (see Figure 13 in the Appendix).

Around one third of the inflation impact compared to the baseline is due to the inflation reanchoring channel, which raises the perceived long-term inflation target by around 9 basis points. This increases the peak impact of inflation by around 15 basis points relative to a calibration without the channel. The impact on near term inflation gets amplified, first, because higher inflation expectations at the lower bound reduce real interest rate rates and stimulate demand and inflation in a self-reinforcing positive spiral. Second, the feedback gets further amplified by the positive impact on asset prices that eases the balance sheet constraints of the financial intermediaries, eases credit conditions and further stimulates demand.

5.3.2 Extending the maturity

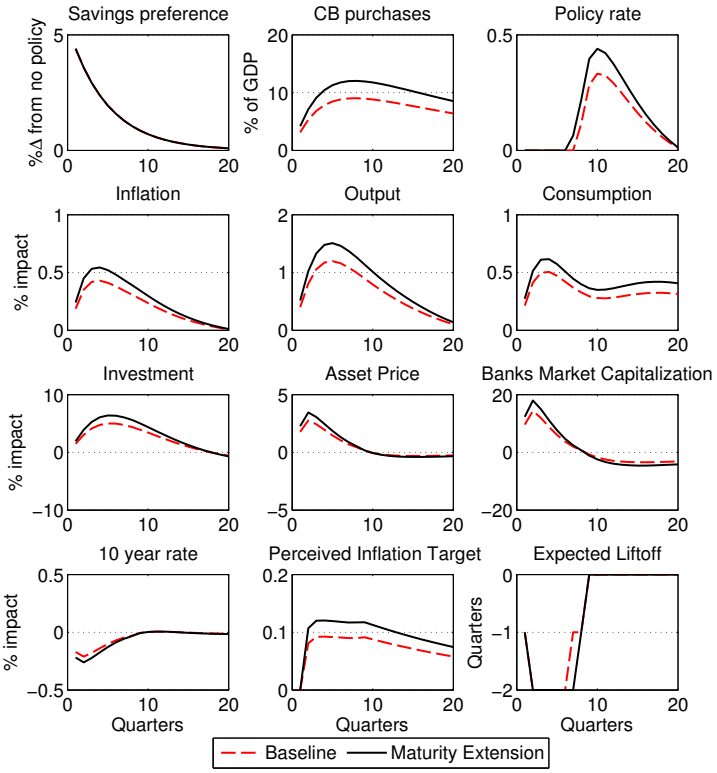
The model can be employed to assess the macroeconomic impact of counterfactual asset purchase policy scenarios. Figure 8 shows the impact of a policy in which the central bank raises the average maturity of purchased assets from 8 to 11 years. This would increase the peak public holdings of assets to 12 percent of GDP in ten-year equivalents. As the figure shows this would make the policy more efficient. Purchasing assets with higher duration would eliminate more interest rate risk from the portfolios of financial intermediaries, which would allow them to extend lending. The policy would increase inflation at its peak by around 50 basis points and GDP by around 1.4 percent.

5.3.3 Interaction with forward guidance

The asset purchase programme improves inflation and output expectations. The policy rule, as a result, would at some future date prescribe higher interest rates, thus shortening the length the period in which the interest rate is expected to stay at its lower bound. The expected interest rate path, therefore, would automatically mitigate the effectiveness of the asset purchase programme. The effectiveness of the asset purchase programme could be improved if the ECB could credibly commit to keep the interest rate at its lower bound longer, despite the improving outlook. Figure 9 illustrates this idea showing the impact of the APP when forward

[32]The average forecast for HICP 2 years ahead increased by 31 basis points in 2 quarters between 2015Q1 and 2015Q2 (by 21 basis points within the first quarter) The cumulative GDP forecast 2 years ahead increased by 75 basis points within the same 2 quarters (by 70 basis points within the first).

Figure 8: Baseline policy vs. a purchases of assets with 11 years to maturity



The figure shows the impact of responses to a baseline policy and an alternative asset purchase policy with extended average maturity (11 years from 8 years).

guidance ensures that the expected lift-off date remains unchanged after the announcement of the asset purchase programme.

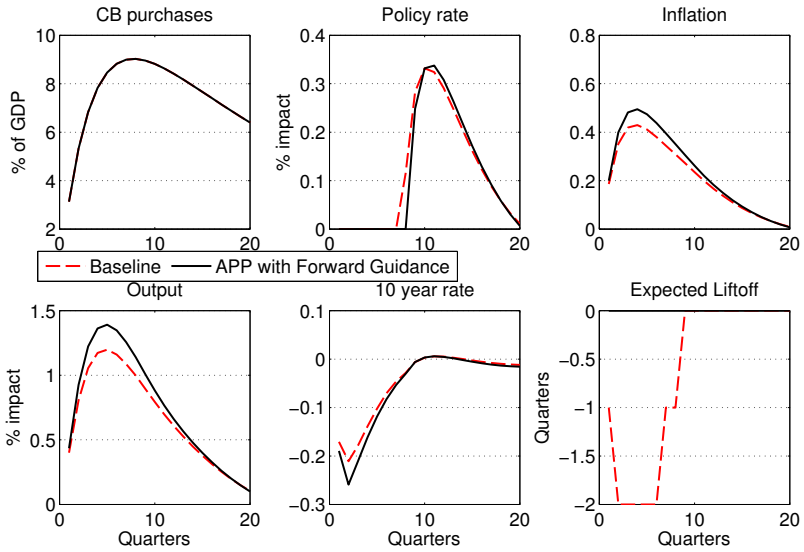
6 Risks of the APP

This section discusses the main risks for the euro area coming from the APP programme. They can broadly be grouped in three categories: i) risks to financial stability; ii) factors that limit the effectiveness of the purchase programme, and; iii) risks of losses on the balance sheet of the ECB.

6.1 Financial stability risks arising from delayed deleveraging of financial institutions

A growing theoretical and empirical literature argues that an expansionary monetary policy over a prolonged period of time can induce financial institutions to engage in riskier activities and exert adverse impact on financial stability. Papers focusing on standard interest rate

Figure 9: Baseline vs. asset purchases with forward guidance



The figure compares the impact of the baseline to an asset purchase programme combined with forward guidance that ensures that the liftoff expectations remain unchanged.

policy typically find an inverse relationship between the level of short-term interest rates and bank risk taking (see e.g. Dell'Ariccia, Laeven and Suarez (2013)). Evidence on the effect of non-standard policy is, however, scant. One notable exception is Chodorow-Reich (2014), which analyses the effect of US unconventional policies conducted between 2008 and 2013 on banks, insurance companies and money market funds. A main finding is that the positive effect of such policies on the stock market and the overall economy improved the solvency position of certain classes of financial institutions, such as banks and insurance companies. Overall, unconventional policies helped to stabilize some sectors of the financial market while provoking some modest additional risk taking in others.

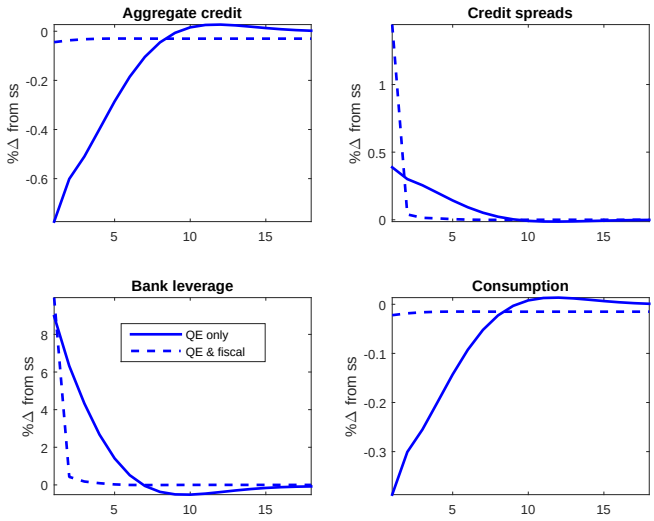
In the euro area, as shown in Section 4, the PSPP has contributed to reduce yields across the entire term structure, with stronger effects being observed on the yield of bonds with relatively higher duration. In the short-term, this flattening of the yield curve has adversely affected the interest rate margins of euro area banks. A prolonged period of low yields can endanger financial stability. This risk is especially high for any banks with an enduring capital shortfall. If banks are unable to raise external capital, lower margins may delay their deleveraging process and impair the recovery of bank lending.

The mechanism outlined above is at the core of the results presented in Correia, De Fiore, Teles and Tristani (2015). The paper compares the effectiveness of a policy of asset purchases in response to a shock that reduces banks' capital to that of an alternative monetary and fiscal policy mix. The mix involves both asset purchases and a policy that subsidizes lending in periods of relatively high credit spreads. The alternative policy mix is used as a benchmark for

comparison because it is highly effective in shielding the real economy from the consequences of large increases in lending rates caused by financial impairments.

The model is a simplified version of the setup presented in Section 5.[33] We use it here to analyse the optimal design of an asset purchase programme in reaction to a shock that reduces banks' net worth. In this framework, in the absence of credit subsidies, a policy of asset purchases is desirable following a deterioration of banks' capital position. This policy relaxes the funding constraint of banks and helps to contain credit spreads, thus contributing to the recovery of credit and real activity.

Figure 10: Asset purchases vs credit subsidies



The figure compares the reaction of key variables in the model to a shock that reduces banks' net worth by 10 percent. The solid line denotes the response when the central bank reacts using a policy of asset purchases. The dotted line denotes the response when the authorities implement a system of credit taxes and subsidies. In both cases, the interest rate is optimally set at zero.

Figure 10 shows the reaction of key variables in the model to a shock that reduces banks' net worth by 10 percent. The solid line denotes the response when the central bank can use interest rate and asset purchases as policy instruments. The effect of the shock is to increase bank leverage on impact. In order to generate profits that help to re-build net worth, banks need to increase credit spreads. This raises firms' financing costs, reduces credit and depresses consumption and real activity. A policy of asset purchases mitigates the increase in credit spreads and the reduction in credit, thus stabilizing the economy. However, by reducing bank interest rate margins, it also delays the deleveraging of financial institutions and the adjustment back to the steady state.

[33] In order to characterize the optimal combination of monetary and fiscal policies, the model is simplified to abstract from capital accumulation, wage stickiness and learning about the central bank's inflation target.

Optimal policy trades-off the desire to cushion the effects of financial disturbances on credit with the need to speed up the adjustment of banks' capital position. A policy that quickly stabilizes credit through large asset purchases conducted over a short period of time would abruptly reduce bank interest rate margins and slow down the accumulation of net worth. Optimal policy implies instead distributing asset purchases over an extended horizon, as currently done under the PSPP. By gradually relaxing the funding constraint of banks, this policy enables them to make sufficient profits to ensure a fast convergence back to the steady state.

The dotted line in Figure 10 shows the response of the economy, when the authorities can implement a system of credit taxes and subsidies. Under this policy, the economy is stabilized on impact. On the one hand, the extension of credit subsidies insulates firms' productive activities by offsetting the impact of increased credit spreads on their financing costs. On the other hand, higher credit spreads allow banks to increase their profits and thus to quickly rebuild net worth.

These findings suggest that the effectiveness of asset purchases is maximised when all banks in the economy are well capitalised. A fiscal intervention is highly desirable when bank leverage is high. Nevertheless, asset purchase policies remain desirable even in the absence of fiscal interventions. Our results in Section 4 are in line with this finding, since the overall reaction of banks' equity prices to the APP announcement has been positive.

6.2 Limits to the effectiveness of asset purchases

The asset valuation channel of the APP operates by reducing the amount of risk held by the private sector, including duration risk. An increase in the relative issuance of long-term bonds by national governments would increase again the exposure of investors to duration risk, offsetting the impact of the asset purchase programme.

In the US, despite successive rounds of quantitative easing policies, the stock of government debt with a maturity over 5 years that was held by the public rose from 8 percent of GDP at the end of 2007 to 15 percent at the middle of 2014. Although part of this change was due to expanding fiscal deficits, Greenwood and Summers (2014) attribute one-quarter to one-third of this increase to the Treasury's active policy of extending the average maturity of the debt. The authors find that, up to July 2014, quantitative easing policies reduced the supply of 10-year duration equivalents by 15.6 percentage points of GDP, while the maturity extension induced by the Treasury's debt policies increased it by 5.5 percentage points of GDP.

In the euro area, the presence of independent fiscal authorities with heterogeneous financing needs creates additional challenges for the co-ordination of monetary and debt management policies. At the same time, the current environment of low and even negative interest rates provides incentives for governments to shorten the maturity of newly issued bonds.

We provide an early evaluation of the impact of national debt policies on the effectiveness of the PSPP, using data on individual bonds from the Amount Outstanding History of the

Bloomberg Data Set. Our sample covers the period from 2014Q2 to 2015Q4. It should be noted that governments can increase duration risk in the economy by either increasing the outstanding stock of debt for a given average maturity, or by extending its average maturity without changing the total outstanding amount. There are two main possibilities of issuing bonds: through issuance of a new bond or through repeated issuance of an existing bond. Similarly, it is possible to redeem bonds by letting them mature or by buying them back. Our dataset enables us to distinguish among new and continued issuances, as well as among maturing bonds and buy-backs.

Since the aim is to evaluate the impact of the PSPP on euro area debt issuance policies, it is natural to restrict the attention to bonds that are eligible under that programme, i.e. all those issued by national governments and supra-national agencies. In order to capture the overall change in duration risk, however, we also include bonds issued by those entities with maturity below 2 years and above 30 years, which are currently not eligible under the PSPP. The sample starts in 2014Q2 because it is challenging to select bonds issued far before the introduction of the PSPP on the basis of the same eligibility criteria.[34]

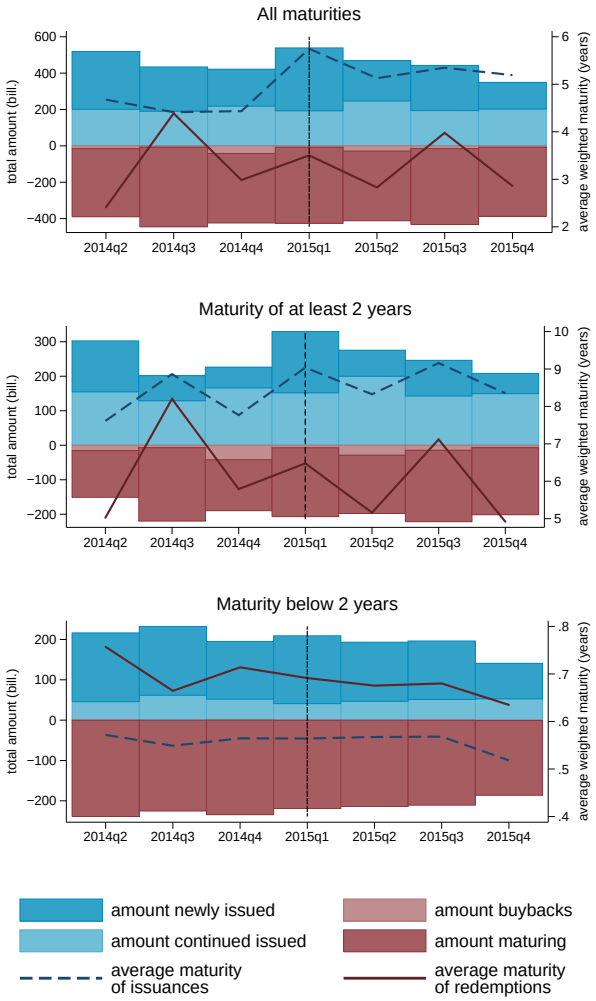
In Figure 11, we document the evolution of the average maturity of all issued bonds relative to that of all redeemed bonds, around the announcement of the PSPP. We base our analysis on remaining maturity, as this is the most relevant concept to capture the economy's exposure to duration risk. The reported measures of average maturity, represented by the dashed and solid lines, weight each bond by its nominal outstanding amount. The figure also reports as coloured areas the total amounts for each category: newly issued bonds (in dark blue), bonds issued during the lifetime of the bond after the initial issuance (denoted as "cont. issued", in light blue), maturing bonds (in dark red), and buy-backs (in light red). The dashed vertical line marks the first quarter of 2015, in correspondence to the announcement of the PSPP. The plot at the top of the figure suggests that the total stock of newly created debt, net of redemption, did not rise over the period considered. The average maturity of net issuances, however, increased. On the quarter of the announcement of the PSPP, the average maturity of issuances was more than 2 years higher than that of redemptions. Moreover, the positive gap between the two measures persisted until the end of the sample.

The middle panel of Figure 11 shows that the increase in the average maturity of issuances relative to redemptions was even larger for bonds above 2 years of maturity, i.e all bonds that were eligible under the PSPP plus those with a maturity above 30 years. The difference is explained by the opposite behaviour observed during the entire sample for bonds with maturity below 2 years, as illustrated in the bottom panel of the figure. The decline in the average

[34]For instance, a bond with a nominal yield of -5 bps in 2013 would have been classified as "ineligible", since its return was below the rate on the deposit facility (zero at that point in time). The same bond would instead have been eligible in 2014, when the rate on the deposit facility was lowered to -10 bps (assuming that the bond would have delivered the same return). The longer the pre-PSPP period covered by the sample, the larger the inaccuracy introduced in the selection of eligible bonds.

Figure 11: Average maturity of bond issuances and redemptions

The dashed blue and solid red lines show the average maturity of issuances and redemptions, respectively. Both measures are obtained by weighting the remaining maturity of each bond by its outstanding amount. Bonds are from all eligible issuers under the PSPP. The dashed vertical line marks the announcement, January 22, 2015. The coloured areas represents total amounts (in billion euros) for each category: newly issued bonds (in dark blue), bonds issued during the lifetime of the bond after the initial issuance ("cont. issued", in light blue), maturing bonds (in dark red), and buy-backs (in light red). The quarterly data spans from April 1, 2014 to December 31, 2015.



maturity of short-term bonds possibly reflects incentives for governments to take advantage of low financing costs, in an environment of compressed and even negative interest rates.

One caveat to this analysis is that redemptions are, by nature, highly volatile. The series can be strongly influenced by individual bonds with large outstanding amounts that mature at a certain point in time. In contrast, issuances are more uniform over time, due to the possibility of reissuing a given bond. Our preliminary findings should therefore be complemented with an

analysis of the full set of newly issued bonds (beyond the eligible ones), over a longer pre-PSPP announcement sample. We leave this for future research.

We evaluate next whether the new issuance policies documented in Figure 11 have changed the amount of duration risk present in the economy.

We first compute the difference between the cumulative net issuance of bonds in 10-year equivalents after the PSPP announcement (over the period 2015Q1-2015Q4) and the cumulative net issuance over the pre-announcement period (over the period 2014Q2-2014Q4). We find that after the PSPP announcement, net issuance increased the supply of 10-years-equivalent debt by 1.9 percent of euro area GDP.

Second, we calculate the reduction in the supply of 10-years equivalent bonds achieved by the PSPP over the period March 9th-December 31th, 2015. This is given by the amount of asset purchases, computed in 10-year equivalents and at remaining maturity, which amounted to 4.5 percent of euro area GDP.

These results suggest that the PSPP has been able to remove duration risk from the economy, despite some increase in the supply of such risk induced by national debt management policies. Our findings point to the importance of ensuring co-ordination between the ECB and national fiscal authorities during the implementation of an asset purchase programme.

6.3 Risk on the balance sheet of the ECB

When engaging in asset purchases, central banks expose themselves to possible losses on their portfolio of risky assets. Asset purchase programmes transfer such risks from the balance sheet of banks to that of the central bank.

A quantitative assessment of solvency risk for the ECB arising from the APP is beyond the scope of this paper. Nonetheless, some lessons can be drawn from the studies by Carpenter, Ihrig, Klee, Quinn and Boote (2013) and Hall and Reis (2013) on the impact of quantitative easing policies on the Federal Reserve's balance sheet. These papers construct projections of the Fed's balance sheet and income statements under a variety of plausible scenario for the future evolution of policy interest rates and of the length of, and exit from, the asset purchases. The main finding is that the size of the future capital losses is likely to be small, i.e. equivalent to few years of monetary income. As a result, remittances to the Treasury could be halted for a number of years when the policy rate starts increasing.

Hall and Reis (2013) also evaluates the resilience of the ECB to sovereign default risk during the period 2009-2013, when the ECB implemented the Securities Market Programme and various long-term refinancing operations. They argue that, in the extreme event of a default, the financial strength of the ECB would depend on whether default is anticipated or unanticipated. In the former case, the price of the bonds purchased through the Securities Market Programme or pledged as collateral in refinancing operations would reflect the possibility of default. The flow coupon income would be low but bond prices would also be low, implying that the capital losses when exiting the crisis would be contained. If default is unexpected,

instead, the ECB could suffer losses from both the impaired coupons during the crisis and the capital losses when exiting - because the price of the bonds at the time of purchases would not reflect the possibility of default. Overall, the ECB's repo position up to 2013 is seen as having significantly limited the risk of instability, because the ECB could only suffer capital losses if banks failed to repay the debt and the loss of collateral value exceeded the haircut.

The results cited above on the impact of quantitative easing policies on the Federal Reserve's balance sheet are broadly applicable also to the APP in the euro area. Relative to the US experience of buying Treasuries (the so-called "QE2" programme whereby the Federal Reserve announced the purchase $600 billion of longer dated treasuries, at a rate of $75 billion per month), the PSPP faces some additional balance sheet risks.

One source of risk comes from the possibility of debt restructuring, which would cause drastic reductions in the value of some of the assets on the balance sheet of the ECB. This risk of QE purchases is unavoidable in the euro area, because there is no area-wide fiscal issuer that can be considered as truly risk free. The provision that PSPP purchases by national central banks are not subject to loss sharing can be understood in the light of this risk. They amount to an implicit fiscal backing, at the national level, of a preponderant fraction of the PSPP portfolio. Concerning the case of corporate bonds, a diversification strategy and appropriate risk mitigation schemes should be adopted in their purchases. Nevertheless, it should also be acknowledged that a successful QE programme would improve macroeconomic conditions and thus tend to reduce the risk of corporate defaults.

A second source of risk arises from the exposure to duration. An earlier or faster than expected recovery would at some point induce the ECB to increase policy interest rates. The adverse impact on the ECB's balance sheet would be stronger, the larger the amount of long-maturity, low-yield bonds held on its portfolio. In the euro area, the APP started at a point in time when the reference policy rate (the MRO) was at 5 basis points and the rate on the deposit facility was at -20 basis points. Since then, many sovereign bond yields have remained in the negative territory. The expected reduction in bond prices along an exit path exposes the ECB to some risk of capital losses, particularly on bonds purchased at negative yields. Moreover, the low sovereign yields also reduce the prospects for asset returns and earnings on the portfolio of bonds for the ECB.

7 Concluding remarks

This paper provides evidence suggesting that the ECB's expanded asset purchase programme was effective in easing further the stance of monetary policy in the euro area economy.

Three transmission channels appear to have been activated. The first one is an asset valuation channel. The increase in the price of sovereign bonds led to a higher valuation of the assets on banks' balance sheets, thus providing them with a form of capital relief. The capital relief mechanism appears to have dominated the countervailing effects on banks' margins of the

flattening of the yield curve. The ensuing reduction in bank leverage can lead to an expansion in lending and support the economic recovery. The second channel through which the APP produced effects is signalling. After the announcement of the programme, market expectations of future short term interest rates edged down, while inflation expectations increased markedly. This combined effect suggests that the downward shift in the yield curve does not reflect a worsening outlook for inflation and GDP growth. Finally, the APP led to a reanchoring of long-term inflation expectations. Our simulations suggest that this channel was also powerful in producing macroeconomic effects.

We do not find evidence of a strong form of market segmentation or of a scarcity channel.

These results suggest a few lessons for the implementation of asset purchase programmes.

First, maximising the duration of the targeted assets would enhance the macroeconomic impact of the programme, for a given size of the purchases. Another option to enhance the impact of the asset valuation channel is to purchase riskier bonds, to the extent that the spread on such bonds is related to investors leverage constraints. The 10 March 2016 Governing Council decision to launch a corporate sector purchase programme can be understood in this light.

Second, more explicit conditional commitments about future policy decisions are desirable to redress the risk of a persistent liquidity trap. This conclusion is consistent with general lessons from the macroeconomic literature (see e.g. Woodford, 2012). One example of such conditional commitments is to communicate the likely evolution of the outstanding central banks asset portfolio over the medium term. From this perspective, the December 2015 Governing Council decisions ("to reinvest the principal payments on the securities purchased under the APP as they mature") provides useful information.

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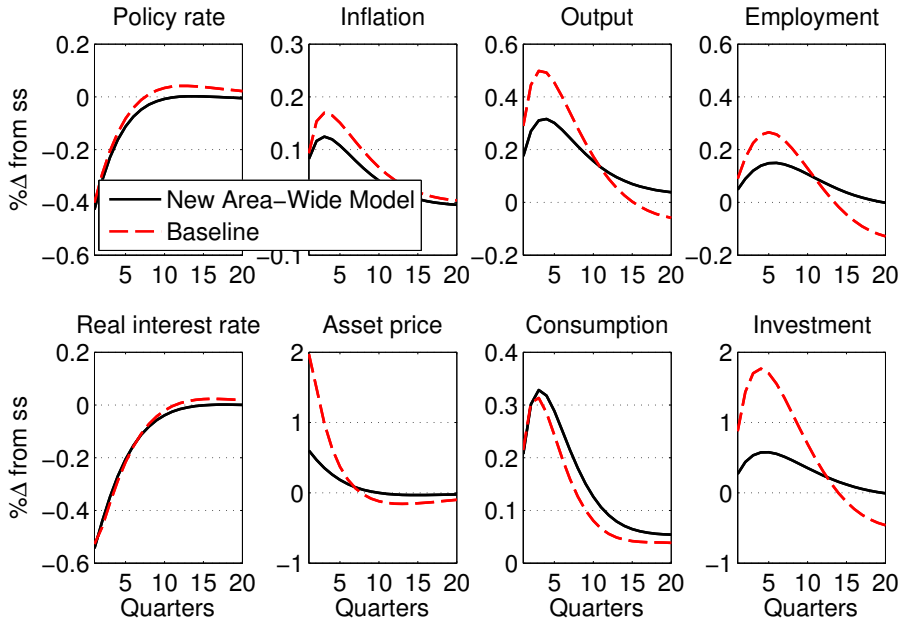
A Macroeconomic impact

Table 10: Calibrated parameter values

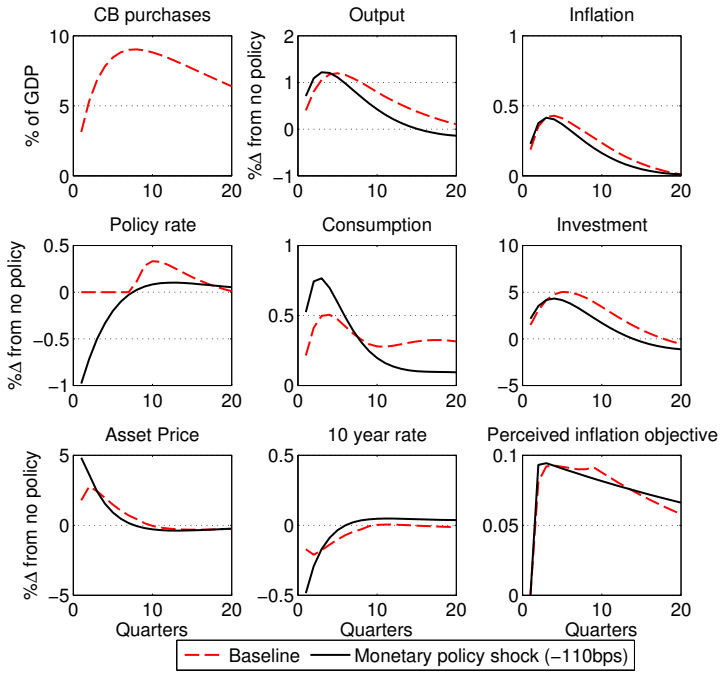
	Households	
β	0.994	Discount rate
h	0.567	Habit parameter
χ	20.758	Relative utility weight of labor
B/Y	0.700	Steady state Treasury supply
$\bar{K}^h/K$	0.000	Proportion of direct capital holdings of the HHs
$\bar{B}^h/B$	0.750	Proportion of long term Treasury holdings of the HHs
κ	1.000	Portfolio adjustment cost
φ	2.000	Inverse Frisch elasticity of labor supply
ϵ_W	4.333	Elasticity of labor substitution
γ_W	0.765	Probability of keeping the wage constant
$\gamma_{W,-1}$	0.635	Wage indexation parameter
$\rho_{\pi^{*p}}$	0.990	Persistence of a shock to the perceived inflation objective
κ	0.0622	Kalman-gain
ς	0.0683	Relative weight of APP surprise
	Financial Intermediaries	
θ	0.315	Fraction of capital that can be diverted
Δ	0.840	Proportional advantage in seizure rate of government debt
ω	0.0047	Proportional transfer to the entering bankers
σ	0.925	Survival rate of the bankers
	Intermediate good firms	
α	0.360	Capital share
δ	0.025	Depreciation rate
	Capital Producing Firms	
η_i	5.169	Inverse elasticity of net investment to the price of capital
	Retail Firms	
ϵ	3.857	Elasticity of substitution
γ_P	0.920	Probability of keeping the price constant
$\gamma_{P,-1}$	0.417	Price indexation parameter
	Government	
$\frac{G}{Y}$	0.200	Steady state proportion of government expenditures
ρ_i	0.865	Interest rate smoothing parameter
κ_π	1.904	Inflation coefficient in the policy rule
$\kappa_{d\pi}$	0.185	Inflation growth coefficient in the policy rule
κ_{dy}	0.147	Output growth coefficient in the policy rule
$\rho_{i,zlb}$	0.500	Interest rate smoothing leaving the lower bound
γ_ψ	0.290	Share of private assets in the purchase program
	Shocks	
ψ	0.018	Initial asset purchase shock
$\rho_{1,\psi}$	1.700	First AR coefficient of the purchase shock
$\rho_{2,\psi}$	-0.710	Second AR coefficient of the purchase shock
e_β	0.044	Initial savings preference shock (β)
ρ_β	0.815	Persistence of the savings preference shock (β)

Figure 12: Macroeconomic impact of an interest rate innovation



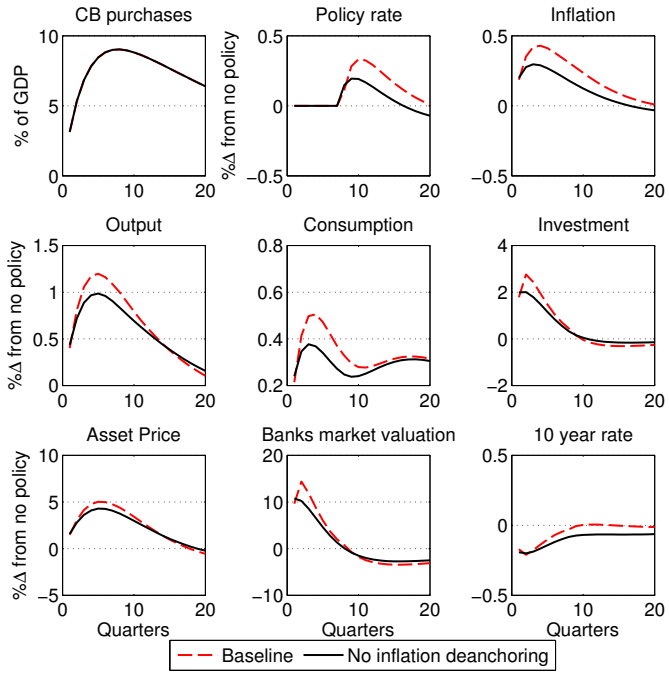
The figure shows the macroeconomic impact of a persistent interest rate innovation as estimated by the New Area-Wide Model and according to the baseline calibration of our model.

Figure 13: Baseline policy impact and a comparable monetary policy shock



The figure compares the impact of the baseline policy to that of a -1.1 percentage point monetary policy shock. The two policies have comparable inflation and output responses.

Figure 14: Amplification effect of the reanchoring channel



The figure compares the impact of the baseline to a scenario where the perceived inflation target is assumed to stay unchanged. The figure shows that, indeed, the impact of the reanchoring channel amplifies the impact of the policy shock.

B Comparison of QE programmes: impact on 10 yrs bond yields

Table 11: Empirical studies on the effects of QE on 10 yrs bond yields (standardized to govt purchase of 10% of GDP)

		Authors	Impact of programme on 10 year sovereign bond yields (if not otherwise indicated)	Impact standardized to 10% of beginning of programme domestic GDP, in bps
EA	APP	Altavilla, Carboni and Motto (2015)	30 bps (event study, 1-day window)	27
			50 bps (event study, 2-days window)	45
		Andrade, Breckenfelder, De Fiore and Tristani (2015)	45 bps (event study, 2 events, 2-days window)	41
		De Santis (2016)	70 bps (error correction model estimated over 09/2014-10/2015)	64
UK	APF1	Joyce and Tong (2012)	100 bps (event study, 6 events, intra-day windows)	71
			150 bps (based on panel regression analysis)	107
		Christensen and Rudebusch (2012)	43 bps (event study, 5 events, 1-day window)	31
		Meaning and Zhu (2011)	27 bps (cross-section regression; effect of local supply on 12 yr bond yields)	53
		McLaren, Banerjee and Latto (2014)	25 bps per ?70bn (regression analysis, impact of local supply effect on bond yields of 5-25 yrs)	66
		Joyce, McLaren and Young (2012)	85 bps (based on a VAR estimated on pre-QE data)	61
		Breedon, Chadha and Waters (2012)	87 bps (dynamic model of the term structure estimated on pre_QE data)	62
JP	CME+	Lam (2011)	24 bps (event study, 5 events, 2-days window)	10
			27 bps (event study, 5 events, 5-days window)	12
	QQE	Fukunaga, Kato and Koeda (2015)	47 bps (event study, 185 events, 2-days window)	22
			33 bps (event study, 173 events, 2-days window)	14
			60 bps (regression analysis, effect of increased purchases and maturity extension)	26

Table 11: cont'd: Empirical studies on the effects of QE on 10 yrs bond yields (standardized to govt purchase of 10% of GDP)

		Authors	Impact of programme on 10 year sovereign bond yields (if not otherwise indicated)	Impact standardized standardized to 10% of beginning of programme domestic GDP, in bps
US	LSAP1	Gagnon, Raskin and Sack (2011)	91 bps (event study, 8 events, 1-day window)	76
			105 bps(event study, 8 events, 2-days window)	88
			55 bps (event study, 23 events, 2-days window)	46
			52 bps (term-premium model estimated over 12/08-03/10)	43
			82 (model of the yield level estimated over 12/08-03/10)	68
		Krishnamurthy and Vissing-Jorgensen (2013)	107 bps (event study, 5 events, 2-days window)	89
		Bauer and Rudebusch (2014)	89 bps (event study, 8 events, 1-day window)	74
		Krishnamurthy and Vissing-Jorgensen (2011)	107 bps (event study, 5 events, 1-day window)	89
		Cahill, DAmico, Li and Sears (2013)	8.9 bps for $100bn purchases (event study, cross-sectional analysis)	119
		D'Amico and King (2013)	33.5 bps (regression analysis; impact of local supply and flow effects)	168
		Swansson (2015)	7.5 bps per $300 bn purchases	38
		D'Amico, English, Lopez-Salido and Nelson (2012)	35 bps (regression analysis)	175
		Ihrig, Klee, Li, Brett and Wei (2012)	38 bps (term structure model estimated on pre-QE data)	32
		Li and Wei (2013)	60 bps (term premium model estimated on pre-QE data)	50
	LSAP2	Cahill, D'Amico, Li and Sears (2013)	9.2 bps for $100bn purchases (event study, cross-sectional analysis)	138
		Meaning and Zhu (2011)	21 bps (cross-section regression; estimate of local supply effect)	53
		Swansson (2015)	7.5 bps per $300 bn purchases (regression analysis)	38
		Swansson (2011)	15 bps per $600 bn purchases (regression analysis)	38
		D'Amico, English, Lopez-Salido and Nelson (2012)	45 bps (regression analysis)	113
		Krishnamurthy and Vissing-Jorgensen (2011)	30 bps (event study, 2 events, 2-days window)	75
		Li and Wei (2013)	19 bps (term premium model estimated on pre-QE data)	48
		Ihrig, Klee, Li, Brett and Wei (2012)	13 bps (term structure model estimated on pre-QE data)	33
		Krishnamurthy and Vissing-Jorgensen (2013)	18 bps (event study, 2 events, 1-day window)	45
	MEP	Krishnamurthy and Vissing-Jorgensen (2013)	7 bps (event study, 1 event, 2-days window)	23
		Cahill, DAmico, Li and Sears (2013)	13.1 bps for $ 100bn purchases (event study, cross-sectional analysis)	175
		Meaning and Zhu (2011)	22 bps (cross-section regression; effect of local supply on 8 yr bond yields)	73
		Hamilton and Wu (2012)	13 bps (regressions analysis based on data for 1990-2007)	43
		Ihrig, Klee, Li, Brett and Wei (2012)	17 bps (term structure model estimated on pre-QE data)	57
		Li and Wei (2013)	19 bps (term premium model estimated on pre-QE data) purchases and maturity extension)	63

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