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Thinking ahead for Europe

QE in the euro area: has the PSPP benefited peripheral bonds?

Ansgar Belke and Daniel Gros

Abstract

The asset purchase programme of the euro area, active between 2015 and 2018, constitutes an interesting special case of Quantitative Easing (QE) because the ECB's Public Sector Purchase Programme (PSPP) involved the purchase of peripheral euro area government bonds, which were clearly not riskless. Moreover, these purchases were undertaken by national central banks at their own risk. Intuition suggests, and a simple model confirms, that, *ceteris paribus*, large purchases by a national central bank of the bonds of their own sovereign should increase the risk for the remaining private bond holders. This might seem incompatible with the observation that risk spreads on peripheral bonds fell when QE in the euro area was announced. However, the initial fall in risk premiums may have been due to expectations of the bond purchases proving effective in lowering risk-free rates. When these expectations were disappointed, risk premiums returned to their initial level. Formal statistical tests confirm that indeed risk premiums on peripheral bonds did not follow a random walk (contrary to what is assumed in event studies). Nor did the announcements of bond buying change the stochastics of these premiums. There is thus no reason to consider the impact effect to have been permanent.

JEL codes: E43, E58, G12, G15

Keywords: European Central Bank, Quantitative Easing, unconventional monetary policies, spreads, structural breaks, time series econometrics

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Table of Contents

List of Figures and Tables

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1. Introduction

Over the last decade, many central banks embarked on large-scale asset purchases in the desire to provide further stimulus while their policy rates were already at the lower bound (Wright, 2012; Swanson, 2017, Swanson and Williamson, 2014). The Federal Reserve was the first to engage in large-scale purchases of public debt securities, amounting in the end to over 20% of GDP. However, it started to do so in 2008/9, when market volatility was close to a peak (Williamson, 2017; Belke et al., 2017).

The ECB's big sovereign bond purchase programme, called the Public Sector Purchase Programme (PSPP) was of comparable size, but it started much later (in early 2015), when market volatility had already subsided. *A priori*, the PSPP thus constitutes a much better measure of the pure 'monetary policy' impact of central bank bond buying. However, there are two reasons why the asset purchase programme in the euro area represents an interesting special case: a) it (also) involved risky assets, namely the bonds of fiscally stressed euro area governments, and, b) the bond purchases were implemented mostly by euro area national central banks (NCBs) and at their own risk.

To our knowledge, ours is the first evaluation of the PSPP which takes both of these two specificities of Quantitative Easing (QE) in the euro area into account.[1]

The second aspect of the PSPP mentioned above is crucial (and often overlooked). Describing the PSPP, as 'the ECB buying hundreds of billions of government bonds' is not correct. The Governing Council of the ECB determines monetary policy, but its decisions are executed mostly by the NCBs of euro area member countries. Normally it does not matter which NCB undertakes a particular operation since the results are pooled. This is similar in the US where the operations decided by the Federal Reserve Board are implemented mainly by the desk of the Reserve Bank of New York. However, the results of these operations are pooled within the entire system.

The key point about QE in the euro area is that this pooling does not apply to the government bond-buying programme (the PSPP), or rather to 80% of it: for this, the predominant part of the PSPP, each NCB only buys the bonds of its own government, and it does so on its own

[1] Dell'Ariccia et al. (2018) cover these key issues in their survey.

account. Thus, the Banca d'Italia has only bought Italian government bonds and the Bundesbank only Bunds.[2]

Strictly speaking, one should furthermore distinguish between the 'Eurosystem' and the ECB. The Eurosystem comprises the legal entity ECB and the participating NCBs. The ECB proper has its own, separate balance sheet, but the decision-making body of the ECB (the Governing Council) decides for the entire Eurosystem. ECB communication has always been careful to make this distinction. However, much reporting in the financial press has been along the lines 'the ECB is buying xxx billions of government bonds'.[3]

The empirical literature on the impact of QE in the euro area has generally ignored the consequences of the lack of pooling of PSPP operations among NCBs.[4] From a purely monetary policy point of view, this lack of pooling should indeed be irrelevant. But this point of view is appropriate only if the bonds of all euro area sovereigns were all riskless and traded at similar rates. However, this was, and still is, not the case. When the PSPP started, the sovereign bonds of several countries, e.g. mainly Portugal, Spain and Italy (Greece did not participate in the PSPP) traded at *substantial risk premiums* over German bonds, which are usually considered the risk-free benchmark. These spreads can only be interpreted as representing expectations that these governments might default at some point in the future.

But if a government were to default, the lack of pooling becomes relevant. If the PSPP had been conducted under the rules for normal monetary policy operations the resulting loss would have been shared by the entire Eurosystem. However, under the rules of the PSPP the result of a default would be very different. An NCB is part of the public sector. When buying government bonds it has to issue its own liabilities, normally short-term deposits of commercial banks. A default by the government on its own national bank constitutes just a transfer within the public sector, but does not change the net debt of the general government – at least so long as the central bank does not default on its liabilities. In a country with its own currency the

[2] The NCBs of some smaller member states with little public debt, e.g. Estonia, were allowed to buy the bonds of international institutions.

[3] As an example see 'ECB Won't Be Able to Help Italy in 2018', which illustrates the key point made here. See web: https://upfina.com/ecb-wont-be-able-to-help-italy-in-2018/.

[4] The role of the ECB (as a separate legal entity) in the PSPP illustrates its peculiar nature. The ECB normally does not participate in monetary policy operations, except in the case of foreign exchange interventions. But the ECB (the separate legal entity) did participate in the PSPP and was tasked mainly to buy the bonds of euro area sovereign financing institutions, the European Stability Mechanism (ESM) and its temporary predecessor, the European Financial Stability Facility (EFSF). The ECB's share in the total bonds bought over the various programmes was about 10 %.

As a result of this, the ECB itself has a larger balance sheet (€430 billion) today than most euro area NCBs. Only those of the four largest NCBs (those of DE, FR, IT and SP) are larger than that of the ECB. However, bond buying by the ECB, about €250 billion, has attracted little attention, maybe because it had so little impact despite the ECB having bought about one half of all outstanding bonds of the ESM.

The profits and losses of the ECB proper are pooled, or shared, *pro rata*, among participating NCBs. This part of the PSPP is the only one for which one can apply the analogy between QE in the US and the euro area.

government could bring about a reduction in the real value of public debt by creating inflation. But this escape route is not possible within the euro area.

The key question is therefore how sovereign bond buying by NCBs changes the expectations of default, and with it, the risk spread (Moessner, 2018, Cohen et al., 2018). Simple intuition suggests that the risk for investors might actually increase when an NCB buys the long-term bonds of its own government (and issues short-term deposits). Should the government become insolvent, the remaining holders of the bonds have to accept a reduction in their claims (see also Reis, 2017, for a similar conclusion). However, a Eurosystem NCB would not be allowed to default on its depositors.[5] But this implies that the residual holders of bonds have to accept higher losses in cases where the NCB holds a significant part of overall public debt. Of course, the PSPP could also lead to lower risk spreads if it were to lower the probability of a default occurring. *A priori*, the impact of the PSPP on risk spreads might thus appear impossible to determine. We provide an explicit model of both mechanisms below and find instead that central bank bond buying (in the euro area) is likely to increase risk spreads, or at least to make them more variable.

The theoretical argument that bond buying by NCBs might actually increase risk spreads seems difficult to reconcile with the finding by many studies that the announcement of the PSPP did lead to an important reduction in risk spreads. We thus discuss whether the impact observed on announcement dates of the PSPP should be considered as temporary or permanent.

One key aspect in this context is that risk spreads are not only embodied in bonds, but also in Credit Default Swaps (CDS). The supply of bonds to the market is affected if the central bank buys them. However, the amounts of CDS outstanding are determined by market participants and thus totally independent of QE operations. This implies that the portfolio balance model, which is usually invoked to justify why central bank bond buying should have an impact on bond prices, is not appropriate for CDS, and thus risk spreads in general.

Consideration of the risk spreads in the context of the PSPP is not just a marginal curiosity. The empirical literature has usually found that the impact of the announcement of the PSPP on risk-less rates, such as longer-term German rates, or on swap rates, was low and often statistically not significantly different from zero. The announcement effects of the PSPP on the three countries with the highest risk premiums mentioned above were several times larger. These three countries account for about one third of euro area GDP. The total impact of the PSPP on average euro area interest rates is thus largely due to the movement of these risk spreads.

The next section provides a short summary overview of the way the PSPP was announced and then implemented. Section 3 presents an illustrative model of the factors that should drive risk

[5] Even apart from this legal point, it is very unlikely that the central bank would default on its liabilities, i.e. the deposits of commercial banks because this would bankrupt the national banking system and provoke additional dislocation costs. Moreover, short-term claims (such as the deposits with the central bank) are usually shielded from losses in most sovereign insolvencies (also in the case of Greece).

spreads. Section 4 discusses the time series properties of the risk spreads to check whether the initial announcement effects should be considered permanent. Section 5 offers our conclusion.

2. QE in the euro area: a short overview

Empirical studies of QE in the euro area face the problem that the likelihood of the ECB engaging in large-scale purchases of sovereign bonds was discussed for a long time while inflation remained below the ECB's target of "close, but below 2%". By contrast, in the US, the first announcement of large-scale asset purchases represented a novelty. The speeches and announcements of November/December 2008 led very quickly to a concrete decision. The dates when markets learned about the first "Large Scale Asset Purchase Programme" can thus be determined with some precision.

By 2014, the US experience (and that of other countries, like the UK) was known and was taken by many as an example to follow. In the euro area, the expectations that large-scale asset purchases would eventually take place built up gradually during the second half of 2014 as inflation and inflation expectations fell. The decisions of November/December 2014 constituted thus much less of a surprise than those of the Federal Reserve 6 years earlier.[6]

This is why, in contrast to studies of QE in the US, most studies of the PSPP use a number of announcement dates, taking the cumulative changes observed over these days as the 'announcement effect'. The exact choice of these dates is somewhat arbitrary, since the hints at the likelihood that the ECB would eventually engage in sovereign bond purchases are not always clear.

We take the 17 announcement dates of Altavilla et al. (2015) as the basis. Other studies use slightly different dates, but generally arrive at similar results. Most evidence on central bank bond buying, commonly referred to as QE, comes from 'event studies'. These studies look at changes in interest rates around the dates when central banks announce their intention to buy large amounts of government bonds. There is a large number of these studies (for surveys, see Borio and Zabai, 2016, Urpschat and Watzka, 2017 and Dell'Ariccia et al., 2018).

The event study methodology is in principle straightforward. Long-term rates are assumed to follow a random walk. This implies that any change observed on announcement dates constitutes a surprise, which is due to the announcement effect itself. Some variants of the event study approach also adjust for the potential impact of other news on the announcement day (Belke et al., 2017). But this yields mostly similar results (as is the case in the example shown below).

As an example of the findings of event studies we report below the results of Altavilla et al. (2015).

[6] Greenlaw et al. (2018) argue that the effects of the Fed's large-scale asset purchases on 10-year yields have been largely overstated.

Table 1. Changes in sovereign bond yields of selected euro area economies around the APP event dates (basis points)

		10-year maturity				
	Euro Area	Euro Area	Germany	France	Italy	Spain
Controlled event study						
1-day change	-30*	-29*	-17	-30*	-75***	-80***
2-day change	-33**	-47*	-18*	-27*	-60***	-65***
Standard event study						
1-day change	-27*	-24*	-16*	-30*	-79***	-78***
2-day change	-36**	-48*	-23*	-36*	-72***	-69***

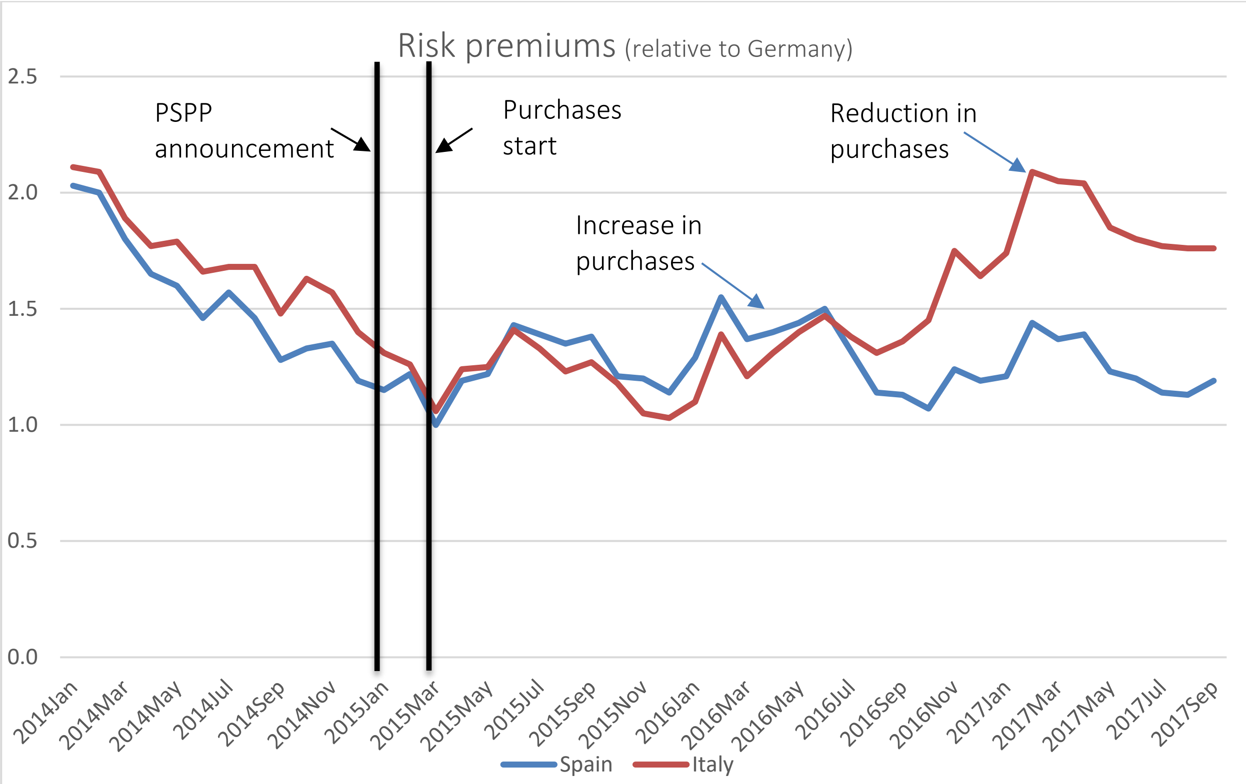
Source: Altavilla et al. (2015). *Notes*: Based on the 17 event dates reported in Altavilla et al. (2015), Table C.1, Appendix C. Asterisks denote statistical significance at the *** 1 percent level, ** 5 percent level, * 10 percent level.

A closer inspection of this table shows a clear tendency that large and significant announcement effects are only observed for the more risky bonds, such as those of Italy and Spain. None of the effects for German and French rates are significant at the conventional 5% level, and the same applies to the euro area average. (Table 2 of Altavilla et al. (2015) finds zero impact on OIS forward rates.) By contrast, for Spain and Italy the effects are highly significant (and several times larger than for Germany).

The combination of small changes in German rates, but larger ones for peripheral countries implies that the risk spread fell on the announcement dates. This implies that most of the overall impact of the PSPP must have come through the compression of risk spreads. The impact of the PSPP on risk spreads is thus key for evaluating the overall effectiveness of the PSPP.

The event study approach thus suggests a strong impact of the PSPP on risk spreads. However, the start of the actual bond purchases was actually followed by an *increase* in rates and spreads. This is shown in Figure 1 below, which shows the risk spread on ten-year Italian and Spanish bonds (i.e. their respective yields minus the rate on ten-year German bonds).

Figure 1. Risk spreads of ten-year Italian and Spanish bonds



Source: Own calculations.

It is apparent that around the announcement these yields fell, but this fall was fully reversed in the few months following the start of the actual purchases on March 9, 2015. This subsequent rebound is irrelevant for event studies since the random walk hypothesis implies that the announcement effect is permanent. The subsequent increase in spreads is implicitly ascribed to the random occurrence of exogenous events.

We will empirically analyse the random walk hypothesis for risk spreads below. Before doing this we address the fundamental question already touched upon in the introduction whether bond purchases by an NCB (under the specific conditions of the euro area) should lead to lower risk spreads.

The usual justification for the hypothesis that bond purchases by the central bank should lower yields is that these purchases reduce the supply of bonds available to investors with a 'preferred habitat', i.e. investors preferring to hold this type of security for non-pecuniary reasons (Woodford, 2012). The fact that government bonds are rated as riskless under banking (and insurance) regulations and the fact that banks have to hold government bonds under regulatory liquidity requirements constitute two examples of why there might be a preferred habitat demand for government bonds.

However, this argument applies to government bonds in general. Within the euro area, banking and insurance regulations treat all government bonds as equal. It is thus not possible to argue that regulation creates a preferred habitat for any particular government bond. Moreover, as already mentioned above, risk spreads are not only embodied in bond yield differentials, but also in CDS. Central bank purchases reduce the supply of bonds. However, the amounts of CDS outstanding are determined by market participants and are thus not affected by purchases under the PSPP. This implies that the portfolio balance model, which is usually invoked to justify why central bank bond buying should have an impact on bond prices, is not appropriate for CDS prices, and thus risk spreads in general.

We thus propose to look at the fundamental factors driving risk spreads to check whether bond purchases by a NCB should be expected to lower risk spreads.

3. Risk spreads and central bank holdings of government debt in the euro area: an illustrative model

This section proposes a simple formal framework to illustrate the mechanisms through which a higher share of central bank holding of national public debt should affect the risk premium.

The framework describes the case of a euro area country whose public debt is in the form of long-term bonds. But this debt trades in the market at a discount to German debt (German government bonds), which is assumed to be riskless.

The reason for the discount or, equivalently, the risk premium is that there is a non-zero probability of default, i.e. that the government of this country, at some point in the future, cannot, or does not want to, service its debt. But default is not certain *ex ante*. The probability of a default is assumed here to comprise two elements:

1. A fixed factor, which depends on the fundamentals of the country, such as the debt/GDP ratio, growth rates, the efficiency of the tax system, etc.[7]
2. A variable factor, which depends on the amount of bonds that have to be refinanced at any point in time. Within the euro area there is the additional risk that even a solvent government might be unable to refinance the debt coming due at that point (de Grauwe and Ji, 2013). The probability of this happening should be an increasing function of the amount of debt still held by the public (holding constant the average maturity).

We formalise these two factors in a simple model of a euro area country with government debt (all in the form of bonds) equal to 1, a share, S, of which is held by the (national) central bank.

The two factors influencing the probability of default can then be formalised as follows:

$$\textit{Probability of default}: PD = \alpha + \beta(1-S), \qquad (1)$$

Where α stands for the fundamental risk of the country and the term β*(1-S) represents the remaining liquidity risk.

[7] Cimadomo et al. (2016) show that risk spreads over German government bonds are a function of expected future fiscal policy.

The fundamental factors driving default risk have been the subject of extensive research, but these factors are just taken as given here since the purpose of this contribution is merely to analyse the impact of central bank bond buying on the riskiness of government bonds (those that remain in the hands of the public). The key issue is whether α can be assumed to be independent of the bond buying itself.

One could of course argue that central bank bond buying should lower the risk-free rate, and thus lead to lower interest rates and a stronger economy throughout the euro area – thereby lowering the α.

Altavilla et al. (2015) pursue a similar reasoning. They argue that bond purchases by the central bank should improve the fundamentals (lower interest rates fostering higher growth), and should thus lead to a lower risk of default. This second-round effect would open the possibility of a positive feedback loop. However, the assumption that bond purchases lead to lower default risk premiums might not be correct, as shown here. If central bank purchases lead, *ceteris paribus*, to a higher risk premium, the feedback would operate in the opposite direction. The impact of bond buying on the fundamentals is thus not clear *a priori*. This is why α is taken here as exogenous. We will come back to this assumption in the empirical part.

The parameter β should be proportional to the inverse of the maturity of government debt. The shorter the maturity, the higher the value of β. In a concrete example, if one compares two countries with the same debt/GDP ratio, say equal to 1 (debt = 100% GDP), differences in (average) maturity of government debt will lead to very large differences in refinancing needs even if the deficit is the same. A weighted average maturity of 5 years implies that the government has to refinance 20% of GDP every year. If the weighted average is 10 years, only 10% of GDP has to be refinanced every year.

In the remainder of this analysis, the average maturity of government debt is assumed to remain constant. The parameter β is thus assumed to be constant, or at least independent of central bank bond buying.

Central bank holdings of government bonds diminish, *pro rata*, the amount which has to be refinanced every period, and thus should diminish, *pro rata*, liquidity risk. This is why the term (1-S) enters the second term of equation (1).

The second key assumption concerns the loss investors must expect if the government defaults. It is assumed here that in a default, debt is cut by the amount R (where R is measured in proportion to the total public debt, which is normalised to one). The reason for a so-called 'hair cut', i.e. a *pro rata* reduction of the value of public debt, is usually to allow the government to start again with a lower debt level, which is sustainable. The amount by which public debt needs to be cut will depend on a number fundamental factors, like expected growth, the ability of the government to raise taxes, etc. These factors are also treated as exogenous here since the focus is on the impact of central bank bond buying, which of itself should not affect the amount by which public debt needs to be cut to make it sustainable. The parameter R is thus treated as given.

If central bank holdings are equal to S, the debt still in the hands of the private sector is reduced to 1-S. At the same time central bank liabilities increase by the same amount S, in the form of short-term deposits of commercial banks. The latter cannot be written down even in a default because a euro area NCB is still part of the Eurosystem, which would not allow it to default on its liabilities. Moreover, reducing the nominal value of commercial bank deposits would bankrupt the banking system. Central bank debt (usually in the form of very short-term deposits) is thus *de facto* senior to other forms of public debt.[8] This implies that the required reduction of the debt, R, has to be spread, proportionally over the remaining bond holders:

$$\textit{Loss given default}: LGD = \frac{R}{(1-S)}. \qquad (2)$$

These two equations can be combined to calculate the expected loss, which for a risk neutral investor should be equal to the equilibrium risk spread. The expected loss is simply equal to the product of the probability of default and the loss given default (expected loss = PD*LGD):[9]

$$Expected\ loss = PD * LGD = risk\ spread = [\alpha + \beta(1-S)]\left[\frac{R}{(1-S)}\right] = R\left[\left[\frac{\alpha}{(1-S)}\right] + \beta\right] \qquad (3)$$

This equation shows that – as long there is a non-zero probability of default even in the absence of liquidity problems (i.e. α >0) – a higher share of debt held by the NCB always leads to a higher expected loss.

$$\partial(risk\ spread)\Big/\partial(S) = \alpha R(1-S)^{-2} > 0 \qquad (4)$$

A higher share of the debt held by the central bank should thus increase the risk spread, as long as both α and R are non-zero.

The underlying reason is that the reduction of the probability of default due to a smaller refinancing risk cannot offset the impact of the higher loss given default. This is due to the smaller amount of debt that can be cut in case of a default, because liquidity risk is not the only reason for a default. If the country has weak fundamentals (α positive), a default can become unavoidable even if there is no liquidity risk because the central bank holds most public debt. And if a default materialises, the bonds remaining in the hands of the general public will suffer a higher loss of value simply because there are fewer bonds on which claims could be reduced.

Equation (4) also implies that bond purchases of the (national) central bank should have no impact on the spread if the country is solvent with certainty (α = 0) and the spread is due only to liquidity risk. This is the result of two opposing forces: central bank purchases reduce the risk

[8] The ECB has stated (ECB, 2015) that purchases under the PSPP will rank *pari passu* with private investors. However, this is irrelevant when an NCB holds the bonds of its own government because the two can be consolidated. If the bonds are reduced in value, future revenues from the central bank to the government will fall by the same amount.

[9] See Camba-Méndez and Serwa (2014). Gros (2018) shows that the risk of redenomination played an additional important role for the Italian risk spread. But this happened only after the formation of the new government in 2018 and is thus outside period of observation considered below.

of a self-fulfilling speculative attack – see equation (1), but they also increase the loss should the attack happen anyway – see equation (2). In this model these two forces just cancel each other out.

So far, the analysis has concentrated on bond holdings by the (national) central bank. Another lesson of the Greek default is that, in a crisis, the bond holdings of commercial banks can also not be written down. The reason is that a default on the bonds held by commercial banks would bankrupt the entire banking system and thus accelerate the recession that anyway accompanies a sovereign default, meaning that, *de facto*, the government, the central bank and the banking system can be treated as one entity in a crisis. This is why, in the case of Greece, the banks in the country participated, *pro forma*, in the exchange of bonds (Zettelmeyer et al., 2013). But the Greek government then needed a loan from the European creditors to recapitalise the banks. The bonds held by the banks were thus *de facto* senior to other holdings. Some foreign banks, e.g. those in Cyprus, also experienced losses that were so large that they had to be recapitalised by their respective governments. But this was a cost to the foreign government. Greek government debt was reduced when foreign banks absorbed losses.[10]

It must be assumed that the Greek example provided the background for expectations of what would happen in case of a default in any of the other peripheral euro area countries. The bond holdings of commercial banks should thus also enter the calculus of the loss given default.

One could thus re-interpret the variable S as the sum of the bonds held by the central bank, denoted by S_{cb}, and the banking system of the country, S_b, with the total bond holdings of the financial sector whose bond holdings would have to be shielded from a default equal to $S = S_b + S_{cb}$. This has several implications.

First of all, it matters whether the (national) central bank buys the bonds from the (national) banking system, or other, non-privileged, investors. The aggregate holdings of the financial sector, S, do not change if the (national) banking system sells its bonds to the central bank, because in this case $dS_b = -dS_{cb}$. This implies that the impact of the announcement of the bond purchase programme by the ECB should depend on the initial expectations of whether the banks in the peripheral countries or other investors would sell their holdings.

Press reports indicate that at the beginning of the purchases in early 2015 it was expected that (commercial) banks would be selling. However, subsequent analysis showed that this was not the case in some countries. One would thus expect spreads to have adjusted in a differentiated way some time after the beginning of the actual purchases.

Own calculations based on Bruegel (2018) shows that there were large differences across countries. For example, in Spain, commercial banks reduced their holdings by a similar amount as the purchases of the Banco d'Espańa, leaving the combined total holdings of the central bank

[10] Reis (2018) assumes that the holdings of banks are not shielded from a sovereign default. But he does not deal specifically with the case of the euro area.

and commercial banks little hanged between end 2014 and end 2018. For Spain one would thus expect little impact of the PSPP on the risk spread.

In Italy, by contrast, commercial banks kept most of their holdings. The purchases of the Banca d'Italia thus led to an increase in the share of public debt held by the combined financial sector from around 35% to over 45%.

The difference between Italy and Spain in the total holdings of the financial sector might be one of the reasons why Italian spreads increased strongly in 2018 after the start of the bond buying, whereas Spanish spreads remained roughly constant.[11]

Equation (4) also implies that a higher share of public debt held by the central bank will make the risk premium respond more to any given change in the two parameters describing the riskiness of the country: α and R. Technically this can be seen by looking at the first derivative of the expected loss with respect to and R. The marginal impact of an increase in the probability of default fundamentals (α) is given by:

$$\frac{\partial Expected\ loss}{\partial \alpha} = \left[\frac{R}{(1-S)}\right] > 0 \qquad (5)$$

which increases with the share of public debt held by the central bank.

The same applies to changes in the parameter R, i.e. the reduction of the debt, which can be expected in case of default. Equation (6) below shows that the impact of any change in R is magnified by the term 1/(1-S), which increases with the share of debt held by the central bank.

$$\frac{\partial Expected\ loss}{\partial R} = \left[\left[\frac{\alpha}{(1-S)}\right] + \beta\right] > 0 \qquad (6)$$

As documented above, the impact of the PSPP on risk-free rates (Bunds and Swap rates) was very limited. This is one of the reasons why it appears appropriate to treat αas exogenous to the bond buying.[12] However, this might not have been anticipated when the PSPP was announced given that many studies of the impact of the Federal Reserve's large-scale Asset Purchase Programmes find significant effects.

One way to reconcile the conclusions of the model with the observations is that investors might have expected a large impact of the PSPP on interest rates and growth in Germany and the rest of the core countries, which would have benefitted peripheral countries as well. In terms of the model, this would have meant a lower α and the impact of the lower α on risk spreads would be magnified by higher central bank holdings.

[11] This increase in the share of debt held by the financial sector is economically relevant. At combined financial sector holdings of 35% (S=0.35) the magnifying effect (1/(1-S)) is equal to about 1.5. When the holdings increase to 46% (S=0.46), the magnifying effect increases to 1.8, an increase of 20%. This would be economically relevant as it would correspond to difference in the risk spread between from 200 and 240 basis points.

[12] Another reason is that empirical studies of the spill-over effects of higher growth in some countries (e.g. Germany) on the periphery find rather low effects, see the references of in 't Veld (2016).

The impact effect of the announcements of the bond buying programme might thus have been temporary because this expectation of a large overall impact did not materialise. This would imply that risk spreads did not necessarily follow a random walk. In the following section we therefore analyse the statistical properties of risk spreads around the announcement (and implementation dates).

4. Event studies, random walks and the efficient market hypothesis

Empirical studies of the impact of central bank bond buying must take into account that sovereign bonds are traded in liquid markets. If these markets are informationally efficient, they will already react to a central bank bond buying programme when it is announced, not only when it is implemented. This is why most empirical studies concentrate on the impact of the announcement of the PSPP on bond prices and thus yields.

These event studies can only measure the 'impact' of QE policies on the day of the event (sometimes they use a 2 day 'horizon'). But a key and often overlooked question is whether the announcement effect is permanent (Andrade et al. 2016, Belke and Gros, 2018, Neely, 2016).

Most studies just assert that the announcement effects should be permanent because under the usual assumption of the efficient market hypothesis (EMH) that bond returns follow a random walk process (Fama, 1970, Lo and MacKinley, 1999), all 'surprises' induced by announcement of central bank bond buying should be permanent.

The idea of stock prices following a random walk is closely connected to that of the EMH. The premise is that investors react instantaneously to any informational advantage they have, thus eliminating any remaining profit opportunities. Hence, asset prices always fully reflect the available information. Moreover, no profit can be made from information-based trading (Lo and MacKinley, 1999). This leads to a random walk where the more efficient the market is, the more random the sequence of price changes turns out to be (Bowsher and Meeks, 2008, Shleifer, 2000).

Event studies use the random walk hypothesis in two ways (Belke, Gros and Osowski, 2017):

1. Announcements rather than actual implementation of the bond buying constitute the decisive moments when market prices move since investors will anticipate the impact of the bond buying.
2. The announcement effect is permanent. The random walk hypothesis implies that the movement of yields on the day of the announcement constitutes a permanent innovation to the future time path of yields.

The random walk hypothesis is thus essential to establish a permanent effect of QE.

Figure 1 below illustrates this view of event studies for the Italian risk premium (or spread) on ten-year bonds using the announcement dates and results of Altavilla et al. (2015). The full line shows the actual data (which incorporate the announcement effects). The dashed line was created by setting for each announcement date the change in the spread to zero (instead of the fall caused by the announcement). After the final announcement (March 2015) the difference between the two lines remains constant (at the value found by Altavilla et al. (2015), namely about 50 basis points).

The figure shows that the risk spread for Italy increased rapidly after the start of the actual bond purchases in March 2015. Under the EMH hypothesis, which underlies event studies, this increase after the start of the purchases has no implications for the effectiveness of the PSPP.[13] The implicit reasoning is that without the PSPP Italian spreads would have increased by the same amount, but from a higher starting level.

Figure 2. Risk premiums - Illustration of implicit reasoning of event studies

Source: Own calculations based on ECB data and Altavilla et al. (2015).

The implicit reasoning of event studies is thus that the macroeconomic benefits of the PSPP can be calculated by using a standard macroeconomic model based on the reduction of the interest rate by the announcement effect for the entire period subsequent to the announcement (Belke and Gros, 2018).

In the following we therefore test the random walk hypothesis for the most pertinent yields and yield spreads of euro area member countries' sovereign bonds.

[13] We just note an inherent contradiction in many event studies. The view that bond buying by central banks is effective is based on a portfolio balance view of the world. But portfolio balance effects can operate only if markets are not efficient, i.e. if there are arbitrage opportunities which cannot be exploited. If markets are not efficient, the price adjustment on the announcement day would not necessarily embody the full anticipated impact of QE, which invalidates the starting hypothesis of the event studies.

We proceed as follows. As a first step, we conduct unit root tests for the levels and first differences of the yields and yield spread time series. As a second step, we check for the significance of autoregressive (AR) components in the first difference of the variables of interest. Any significant AR component indicates a violation of the efficient markets hypothesis.

Data and variables

We tested the EMH on the 10yr government bond yields and the corresponding spread (=difference relative to German yields) for Spain, France, Greece, Ireland, Italy and Portugal. Our sample period ranges from 2 September 2013 to 15 January 2018 (over one thousand days). The data source is Datastream.

Unit root tests

In Table 2 we present the results of Augmented Dickey Fuller (ADF) tests.

Table 2. Results of unit root tests (ADF test statistics and probabilities)

Variable	Level	First difference	Lag length (level, first differences)	Integration order of variable
Gov Yield DE	-2.09 **(0.2478)**	-33.78 (0.0000)	0,0	I(1)
Gov Yield ES	-2.98 (0.0370)	-34.21 (0.0000)	0,0	I(0)
Gov Yield FR	-2.16 **(0.2216)**	-33.74 (0.0000)	0,0	I(1)
Gov Yield IR	-3.35 (0.0128)	-32.25 (0.0000)	0,0	I(0)
Gov Yield IT	-2.66 (0.0814)	-33.76 (0.0000)	0,0	I(0)
Gov Yield PT	-2.80 **(0.0587)**	-31.01 (0.0000)	1,0	I(1) borderline
Spread ES	-3.63 (0.0056)	-26.73 (0.0000)	0,1	I(0)
Spread FR	-2.81 **(0.0564)**	-35.44 (0.0000)	0,0	I(1) borderline
Spread IR	-3.30 (0.0153)	-33.25 (0.0000)	0,0	I(0)
Spread IT	-3.07 (0.0289)	-26.51 (0.0000)	0,1	I(0)
Spread PT	-2.34 (0.1599)	-31.06 (0.0000)	1,0	I(1)

Source: Compiled by authors. *Note*: Table displays empirical realisations of the Augmented Dickey-Fuller test with a constant (MacKinnon (1996) one-sided p-values). The sample period ranges from 8 February 2013 to 15 January 2018. The lag length of the ADF test equation (third column) was determined by the Schwarz information criterion.

We find that the random walk hypothesis is rejected for many variables, especially Spanish, Irish and Italian yields and, even more significantly, Spanish, Irish and Italian spreads over German bonds.

A similar result is obtained when one estimates an autoregressive equation for the first differences in the different yields (and the spreads). Table 3 shows the empirical realisations of autoregressive coefficients in autoregressive (AR)-estimations for the first differences in the yields and the spreads.

Table 3. Results from AR-regressions (first differences)

Variable	Lag 1	Lag 2	
Gov Yield DE	/	-0.052 (0.0780)	Borderline
Gov Yield ES	/	-0.058 (0.0509)	Borderline
Gov Yield FR	/	/	
Gov Yield IR	/		
Gov Yield IT	/	-0.067 (0.0184)	
Gov Yield PT	0.086 (0.0035)	/	
Spread ES	/	-0.112 (0.0001)	
Spread FR	/	-0.049 (0.1003)	
Spread IR	/	-0.064 (0.0295)	
Spread IT	/	-0.097 (0.0010)	
Spread PT	0.083 (0.0048)	/	

Note: The table displays empirical realisations of autoregressive coefficients in AR-estimations for the first differences in the yields and the spreads. Only significant entries are displayed. In the case of Spain lags 4 and 5 also enter with a significant negative sign. In the case of Ireland the significant lag four is also included with a negative sign. In the case of Italy lags 4 and 5 are also significant with a negative sign and for Portugal lags 3 (significant, with a positive sign), 4 and 5 (both with a significant negative sign) enter as well. The complete estimated AR equations are available on request. For further details see Table 1.

Processes of first differences cannot be rejected to follow a white noise process in the case of France (yields and borderline also spreads) and Ireland (borderline yields). However, in the cases of Germany, and the financially distressed countries at that time – Spain, Ireland (for spreads), Italy and Portugal – we find significant AR components. Except for Portugal, bond returns and spreads exhibit (very significant) negative autocorrelation – which implies that shocks tend to be reversed over time. More broadly, this implies that the hypothesis of a random walk is rejected by the data for the spreads of 3 of the 4 the peripheral countries considered here. The basic hypothesis necessary for event studies is thus rejected by the data.

One reason for our finding that the market for some government bonds was not efficient is that short sales of government bonds were prohibited in the EU after 2012 (European Commission, 2012). This ban on short sales implies in particular that on days when markets reacted strongly to PSPP announcements it was impossible for arbitrageurs to shorten bonds. The ban on short sales could thus have contributed to a delayed adjustment to initial over-reactions on the QE announcement days used in event studies.

The finding that the positive impact of bond purchases has only been temporary for yield spreads of fiscally stressed countries should not be surprising given the results of the model presented above. The NCBs are part of their respective national public sectors, and it is difficult to see why the risk spread should fall permanently when one arm of the government buys the debt of another.

Structural break tests of AR-models – Checking the euro QE event dates

Basic breakpoint tests

As a further step, we conducted structural break tests of our estimated AR-models with the euro QE event dates identified by Altavilla, Carboni and Motta (2015) as candidates for potential breaks. The purpose is to check whether the announcement, or rather the implementation led to a change in the stochastic properties of the spreads. One of the conclusions of the model had been that it makes a difference whether the sellers of the bonds (bought by NCBs) were banks in the home country, or other, foreign or domestic non-privileged bond holders. Whether this would be the case was not known at the time of the announcement. As this uncertainty cleared up when implementation started, the model would predict a change in the stochastic property as the spread should react more to changes in economic circumstances and further PSPP announcements. In the following, we concentrate on the F-statistic version of the Chow breakpoint test.[14]

We focus only upon the two most important countries with significant risk premiums, namely Spain and Italy. Table 4 below displays the results of our Chow breakpoint tests of our estimated AR equations for Spanish and Italian bond spreads. In each case, the potential breakpoint tested corresponds with the 17 euro QE event dates identified by Altavilla, Carboni and Motto (2015).

[14] The F-statistic has an exact finite sample F-distribution if the errors are independent and identically distributed normal random variables. The likelihood ratio- and Wald test-versions of the Chow breakpoint tests were also applied and the results point in the same direction as the F-statistic variant. The results are available on request.

Table 4. Chow breakpoint tests for Spanish and Italian spreads

	F-statistic and Prob. F(4,1113)	
Altavilla, Carboni and Motto (2015) QEuro event dates	Spain	Italy
September 04, 2014	1.240737 (0.2918)	0.726193 (0.5741)
September 12, 2014	1.405600 (0.2299)	0.910499 (0.4570)
September 24, 2014	1.521208 (0.1937)	0.866501 (0.4834)
September 25, 2014	1.513721 (0.1959)	0.872967 (0.4795)
October 02, 2014	1.400276 (0.2317)	0.803029 (0.5233)
October 10, 2014	1.348563 (0.2499)	0.781842 (0.5370)
October 24, 2014	1.198844 (0.3096)	0.882562 (0.4737)
November 06, 2014	1.140273 (0.3360)	0.810825 (0.5183)
November 17, 2014	1.212272 (0.3038)	0.841227 (0.4990)
November 21, 2014	1.217500 (0.3016)	0.889943 (0.4692)
November 27, 2014	1.307836 (0.2615)	0.961367 (0.4278)
December 04, 2014	1.495174 (0.2014)	1.152026 (0.3305)
January 02, 2015	1.825637 (0.1215)	1.222049 (0.2996)
January 08, 2015	1.711119 (0.1452)	1.125978 (0.3427)
January 14, 2015	1.905046 (0.1073)	1.413066 (0.2274)
January 22, 2015	**2.503765 (0.0408)**	1.661688 (0.1566)
March 05, 2015	**2.846545 (0.0230)**	**2.417371 (0.0470)**

Notes: Chow breakpoint test: 9/04/2014 applied to respective estimated AR equation. Null hypothesis: No breaks at specified breakpoints. Varying regressors: all equation variables. Equation sample: 9/02/2013 1/15/2018. Total number of observations: 1113, number of parameters in the equation: 4.

We do not find much evidence of a structural break in the estimated AR equations for Spanish and neither for Italian bond spreads prior to 5 March 2015, which was essentially just a few working days before the start of actual purchases. The piecemeal announcement thus does not seem to have changed the stochastic properties of the spread time series. When implementation became imminent, it was presumably also clearer whether home banks would be large sellers.

In the case of Spanish spreads, there is weak evidence of one further breakpoint in addition to 5 March 2015, namely at the occasion of the precedent-setting ECB press conference on 22

January 2015, at which Mario Draghi announced the central bank's expanded asset purchase programme (and a small interest rate cut).

Complementary breakpoint tests

The evidence of a lack of breakpoints prior to 5 March 2015, is underscored again by the results of *complementary breakpoint tests* which do not focus on predetermined dates. For this purpose we applied the Quandt-Andrews unknown breakpoint test and the Bai-Perron multiple breakpoint test.[15]

The *Quandt-Andrews breakpoint test* tests for one or more unknown structural breakpoints in the sample for a specified equation. The idea behind the Quandt-Andrews test is that a single Chow Breakpoint Test is performed at every observation between two dates. The test statistics from those Chow tests are then summarised into one test statistic for a test against the null hypothesis of no breakpoints. It thus tests the null hypothesis of no structural breaks in any of the parameters of the estimated equation (Andrews, 1993).

The *Bai-Perron multiple breakpoint test* represents a generalisation of the Quandt-Andrews breakpoint test and tests the null hypothesis of no structural change against an unknown number of breaks in all parameters of the estimated model.

Table 5. Complementary breakpoint tests – Spanish spreads

a) *Quandt-Andrews unknown breakpoint test for Spanish spreads*

Quandt-Andrews unknown breakpoint test
Null hypothesis: No breakpoints within 15% trimmed data
Varying regressors: All equation variables
Equation sample: 9/02/2013 1/15/2018
Test sample: 4/30/2014 5/19/2017
Number of breaks compared: 798

Statistic	Value	Prob.
Maximum LR F-statistic (7/03/2015)	8.333721	0.0000
Maximum Wald F-statistic (7/03/2015)	33.33488	0.0000
Exp LR F-statistic	1.095874	0.0986
Exp Wald F-statistic	11.17192	0.0001
Ave LR F-statistic	1.766287	0.0682
Ave Wald F-statistic	7.065147	0.0682

Note: probabilities calculated using Hansen's (1997) method.

[15] We also inspected recursive residuals, recursive parameter estimates and the results of CUSUM of squares tests. The results pointed in similar directions and are available on request.

b) Bai-Perron multiple breakpoint test for Spanish spreads

Multiple breakpoint tests
Bai-Perron tests of L+1 vs. L sequentially determined breaks
Date: 03/10/18 Time: 10:45
Sample: 9/02/2013 1/15/2018
Included observations: 1,141
Breaking variables: C DSPREAD_ES(-2) DSPREAD_ES(-4) DSPREAD_ES(-5)
Break test options: Trimming 0.15, Max. breaks 5, Sig. level 0.05

Sequential F-statistic determined breaks:			**1**
Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	8.333721	33.33488	16.19
1 vs. 2	2.484644	9.938576	18.11

* Significant at the 0.05 level.
** Bai-Perron (Econometric Journal, 2003) critical values.

Break dates:

	Sequential	Repartition
1	7/03/2015	7/03/2015

The *Quandt-Andrews breakpoint test* rejects the null hypothesis of no structural breaks in any of the parameters of the estimated AR-equation for Spanish spreads in three model variants only at the 10 percent significance level but in the other three cases at the 1 percent level (Table 5a). Hence, at least based on the Quandt-Andrews breakpoint test, overall we *have to reject* the null hypothesis of *no structural breaks* in the AR equation estimated for Spanish yields.

Based on the empirical results of our *Bai-Perron multiple breakpoint test* we also have to reject the null hypothesis of no structural change in the AR equation estimated for Spanish spreads (Table 5b). More concretely, we identify exactly one breakpoint located at 7 March 2015 ("sequential" and "repartition"). To summarise, this procedure yielded one breakpoint, namely the start of actual bond buying. This finding is difficult to reconcile with the hypothesis underlying event studies that the entire impact of bond purchases can be measured at the announcement date(s).

Table 6. Complementary breakpoint tests – Italian spreads

a) Quandt-Andrews unknown breakpoint test for Italian yields

Quandt-Andrews unknown breakpoint test
Null hypothesis: No breakpoints within 15% trimmed data
Varying regressors: All equation variables
Equation Sample: 9/02/2013 1/15/2018
Test Sample: 4/30/2014 5/19/2017
Number of breaks compared: 798

Statistic	Value	Prob.
Maximum LR F-statistic (7/06/2016)	3.005744	0.2107
Maximum Wald F-statistic (7/06/2016)	12.02298	0.2107
Exp LR F-statistic	0.688064	0.3693
Exp Wald F-statistic	3.645531	0.1840
Ave LR F-statistic	1.248390	0.2423
Ave Wald F-statistic	4.993560	0.2423

Note: probabilities calculated using Hansen's (1997) method.

b) Bai-Perron multiple breakpoint test for Italian spreads

Multiple breakpoint tests
Bai-Perron tests of L+1 vs. L sequentially determined breaks
Sample: 9/02/2013 1/15/2018
Included observations: 1,141
Breaking variables: C DSPREAD_IT(-2) DSPREAD_IT(-4) DSPREAD_IT(-5)
Break test options: Trimming 0.15, Max. breaks 5, Sig. level 0.05

Sequential F-statistic determined breaks:			0
Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1	3.005744	12.02298	16.19

* Significant at the 0.05 level.
** Bai-Perron (Econometric Journal, 2003) critical values.

Based on the results of our *Quandt-Andrews breakpoint test* we can clearly *not reject the null hypothesis of no structural breaks* in any of the parameters of the estimated AR-equation for Italian spreads in even at the 10 percent significance level and in any model variant (Table 6a).

Also the empirical results of our *Bai-Perron multiple breakpoint test* let us *accept* the null hypothesis of *no structural change* in the AR equation estimated for Italian spreads against an unknown number of breaks in all parameters of the estimated model (Table 6b). To summarise, we do not find any breakpoint in the estimated AR-processes for the first differences in the Italian spreads. This confirms again that the announcement of the PSPP did not lead to a structural break in the AR relationships found above, which in turn led to a rejection of the random walk hypothesis necessary for event studies to identify permanent effects.

5. Concluding remarks

The title of a recent Brookings conference, “Quantitative easing lowered interest rates. Why isn’t quantitative tightening lifting them more?”, encapsulates the conundrum facing central bankers as they exit their balance sheet expansion policies (Belz and Wessel, 2018). The conundrum is particularly acute for the ECB, which has terminated its programme of buying public sector bonds (PSPP) as of January 2019, although risk-free interest rates (and expected inflation rates) in the euro area were at about the same level as when the ECB started to buy sovereign bonds.

Our explanation is simple: the ECB’s bond buying programme might have lowered rates when it was announced, but the impact was transitory. The data reject decisively the random walk hypothesis necessary for event studies to measure a permanent effect. The restrictions on short covering on sovereign bonds enacted

We show that QE in the euro area was special because most of the sovereign bond purchases were undertaken by NCBs on their own account. Previous empirical studies of the PSPP have usually neglected this institutional fact, which is key to understanding the behaviour of risk spreads.

Event studies suggest that the announcement of the sovereign bond purchasing programme in the euro area had a strong impact on risks spreads for peripheral government bonds. However, these spreads increased again after the bond buying started. Moreover, a simple model of the risk for private investors suggests that larger holdings by NCBs increase the risk for the remaining private investors because the liabilities of central banks cannot be curtailed in the case of a sovereign default.

Our explanation of this seeming contradiction is simple: the announcement of the bond buying programme in the euro area might have lowered risk rates because it was expected that, as in the US, this would lead to substantially lower risk-free rates. But this did not materialise. The impact effect on German rates was not significantly different from zero at conventional thresholds (and that on OIS rates was zero). Moreover, our model predicts that the risk for private bond holders should not be affected if (the national) central banks buy the bonds mostly from the banking sector. Whether or not this was going to be the case could only be guessed at when the policy was announced.

This information, of what sector was reducing its sovereign bond holdings could diffuse only gradually. This is consistent with the observation that it was not the announcement, but the actual bond buying that influenced the time series pattern of spreads over time.

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