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Jan Willem van den End

DeNederlandscheBank

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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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De Nederlandsche Bank NV
P.O. Box 98
1000 AB AMSTERDAM
The Netherlands

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Jan Willem van den End [a]

[a] *De Nederlandsche Bank, the Netherlands*

Abstract

We show that through the safe asset channel the excess liquidity created by QE can lead to higher sovereign bond spreads in the euro area. This unintended effect is most likely in stressed markets when excess liquidity spurs demand for tradeable safe assets, pushing down the interest rate of these assets, which widens risk spreads. Outcomes of a panel regression model estimated for individual euro area countries confirm that the excess liquidity created by QE had an upward effect on sovereign bond spreads. It indicates that the safe asset channel dominates the usual portfolio rebalancing channel. For monetary policy the results imply that QE is not an appropriate instrument to address country specific shocks.

Keywords: interest rates, central banks and their policies, monetary policy.
JEL classifications: E43, E58, E52.

* *Email addresses*: w.a.van.den.end@dnb.nl (J.W. van den End). We thank Dennis Bonam, Maurice Bun, Gavin Goy, Roel Grandia, Yvo Mudde, Fons van Overbeek, Christiaan Pattipeilohy, Sweder van Wijnbergen and participants of the DNB research seminar (Amsterdam, 2018) and participants of the International Risk Management Conference (Milan, 2019) for their comments on a previous version of the paper and Daniël Overduin and Martin Admiraal for collection of the data. Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

1. Motivation

Since 2015 the Public Sector Purchase Programme (PSPP) has been the main instrument for Quantitative Easing (QE) in the euro area. While net asset purchases under the PSPP ended in 2018, the ECB has communicated that QE will remain part of the toolbox in the future. It is foreseen as an instrument of monetary policy that will be used for contingencies (Draghi, 2018). Until now, the objective of the PSPP has been to raise inflation in the euro area through lowering the risk-free interest rate and flattening the yield curve. The programme was not intended to target credit spreads or credit risk premia on government bonds; those bonds are purchased in proportion to the capital key of EMU member states.[1] Nevertheless, in the literature the question has risen how effective QE would be to deal with asymmetric shocks to individual countries. Bletzinger and Von Thadden (2018) explore this use of QE in a theoretical framework and conclude that a PSPP-type of QE would be effective to address asymmetric shocks if there are no structural differences in monetary transmission across countries. However, if countries have different financial structures they conclude that the central bank should concentrate the asset purchases on the country where banks are more exposed to their own sovereign.

The ECB has applied such more targeted monetary instruments before. With so called credit easing instruments it has responded to asymmetric shocks which threatened monetary transmission. Those instruments target specific stressed markets, such as the asset-backed securities market. Compared to such targeted measures, QE has more indirect effects on financial markets. It creates excess liquidity and this is assumed to lead to portfolio rebalancing by investors towards more risky assets. Such risk-taking compresses risk premia across the board. Hence, next to the direct effects of asset purchases on risk premia, there are potential indirect (rebalancing) effects for which the central bank is dependent on the behavior of market participants.

In this paper we focus on such indirect effects of government bond purchases in a QE programme. It relates to the preferred-habit literature that includes demand and supply factors in interest rate models. While this literature focusses on the impact of changes in safe asset supply on bond yields, we focus on the impact of excess liquidity created by QE on relative demand and supply of safe assets[2] and sovereign bond spreads, through the safe asset channel. We first analyze this channel in a stylized framework, which is inspired by Caballero and Farhi (2017). Through the safe asset channel, excess liquidity can stimulate demand for tradeable safe assets, most likely by non-banks which do not have access to the safe asset of central bank reserves. Grandia et al. (2019) show that PSPP purchases substantially changed the composition of outstanding high quality liquid assets by turning marketable securities (available to all economic agents) into non-marketable assets (reserves available to banks

[1] In practice central bank purchases of government bonds can have different and non-linear effects on sovereign yields of individual euro area countries given the different market structures and dynamics across EMU countries.

[2] Safe assets are defined as "unconditional financial promises with no credit risk, so that nominal repayment is certain" (Golec and Perotti, 2017).

only), with implications for the competition between banks and other economic agents for tradeable safe assets. Non-banks with a preference for such assets will likely invest in risk-free (safe) government bonds. The preference for such assets will be particularly high in stressed market conditions. Additional safe asset demand goes with risk-shedding, i.e. a switch from risky assets to safe government bonds in investment portfolios. The rebalancing towards safe assets creates a scarcity premium in the interest rate of safe bonds and a rising spread between safe and risky bond yields. The yield spread primarily is a cyclical phenomenon, driven by risk aversion. If risk aversion declines again, relative demand for safe assets falls and the equilibrium in the market for tradeable safe assets is restored.

An increasing risk premium can limit the full transmission of monetary policy across the whole risk spectrum. It means that, although the level of interest rates may be reduced in all EMU countries as a result of QE, financial conditions are loosened more in safe asset markets than in risky asset markets due to the safe asset channel. This leads to uneven transmission of monetary policy across EMU countries, taking into account that the risk premium determines marginal investments and the allocation of capital in the economy, This questions the effectiveness of using QE in the form of the PSPP (i.e. central bank purchases of sovereign bonds according to the capital key of EMU countries) to address country specific shocks.

We empirically test the effects of the safe asset channel on sovereign bond spreads, by estimating a panel regression model for four peripheral euro area countries. The model takes into account both the announcement effects of QE on spreads and the anticipation effects. The latter are included by a news variable, being the number of news items about the QE policy of the ECB, as used in other studies. By controlling for anticipation effects we also address endogeneity concerns. The estimation outcomes show that the effects of QE on sovereign spreads are conditional on the market situation; in stressed markets the excess liquidity has an upward effect on sovereign spreads, likely due to increased demand for safe assets. Over the whole sample period (2014-2018), this safe asset channel seems to dominate the usual portfolio rebalancing channel, since on average QE announcements and the change of liquidity are associated with higher sovereign bond spreads. In contrast to that, anticipation effects had a downward effect on sovereign spreads, which may be the result of increased risk-taking. The different directional effect of announcement versus anticipation effects on sovereign spreads suggest that portfolio rebalancing in anticipation of QE was unwound after the announcement. All in all the outcomes suggest that although QE has loosened financial conditions by lowering interest rates, they decreased less for risky than for safe assets in line with the safe asset channel. This leakage effect to safety is enlarged if risk-aversion is high.

The rest of this paper is organized as follows. In the next section the PSPP is compared to the previous sovereign bond purchase programme of the ECB. Section 3 provides an overview of the related literature. Section 4 presents an analytical framework of the safe asset channel, which is empirically tested in section 5 with a panel regression model. Section 6 presents the estimation outcomes and section 7 some robustness checks. The last section concludes.

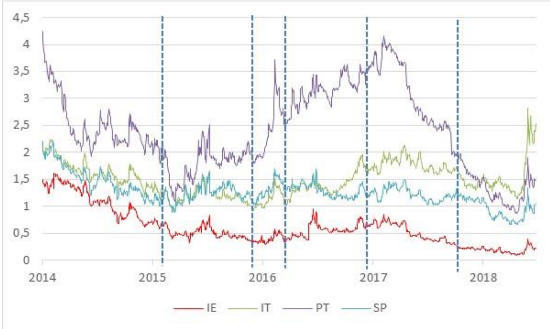
2. Credit easing vs QE

Stress in sovereign bond markets prompted the ECB in 2010-12 to purchase sovereign bonds by the Securities Market Programme (SMP). The objective of this programme was to address the malfunctioning of the Greek, Irish, Portuguese, Italian and Spanish bond markets, which were hit by asymmetric shocks. This qualifies the SMP as a credit easing instrument, targeting stressed market segments and signaling that it aimed at lowering sovereign spreads. By only purchasing government bonds in stressed markets the SMP did not reduce the supply of tradeable safe assets. This is distinct from quantitative easing by the PSPP, which aims at the euro area as a whole by government bond purchases in proportion to the capital key of EMU countries. By also purchasing AAA government bonds, the programme has reduced the supply of tradeable safe assets. Another difference between the SMP and PSPP is that the excess liquidity created by bond purchases was sterilized in the former and not in the latter programme. This implies that the SMP principally only had a direct (announcement and implementation) effect on bond yields in stressed markets and not an indirect portfolio rebalancing effect driven by excess liquidity. In practice however, there is not much difference between the SMP and PSPP with regard to the creation of excess liquidity, since the liquidity created by the SMP was sterilized by two week central bank deposits and the PSPP with overnight deposits. Hence the main difference between both programs is their effect on tradeable safe asset supply.

Empirical studies show that the SMP had a downward effect on the yields of sovereign bonds that were targeted (see ECB, 2014 for an overview). Although those studies usually do not include sovereign spreads as dependent variable (but bond yields as such), Figure 1 shows that the bond spread of countries eligible for the SMP over German bond yields declined at the announcement of the SMP in May 2010. A main reason for this is provided by Beetsma et al. (2014), who find that the SMP reduced flows of flight-to-safety capital from stressed to non-stressed countries. This implies that risk free yields, German bond yields in particular, did not decline due to a demand for safe assets, which supported the decline of sovereign bond spreads. Compared to the SMP, the announcement effect of the PSPP on bond spreads of peripheral countries is less obvious. Figure 2 shows that on days at which changes to the PSPP programme were announced (next to the start early 2015 it also refers to adjustments of the monthly purchase amounts or extensions of the horizon of the programme), the effects on sovereign bond spreads are less clear. In Sections 5 and 6 we formally test the effect of the PSPP on sovereign bond spreads.

Figure 1. Effect SMP on sovereign spreads

Figure 2. Effect PSPP on sovereign spreads



Note: sovereign spreads are defined as the difference between the 10 years government bond yield of the country concerned and the German 10 year bond yield. The horizontal lines represent the announcement dates of the SMP (introduction of programme) and the PSPP (introduction and changes of programme).

3. Literature review

Our paper relates to strands of the literature which include demand and supply factors in interest rate models. In traditional standard no-arbitrage term structure models the relative supply of bonds does not affect prices in deep and liquid financial markets, such as government bond markets. These models assume there is no market segmentation. This is different in the preferred-habitat literature, which assumes that "preferred-habitat" investors prefer specific maturities, which makes that the interest rate for a given maturity is influenced by demand and supply shocks specific to that maturity (Modigliani and Sutch, 1966, 1967). This strand of the literature has developed further by studies which investigate the impact of central bank asset purchases on bond yields. Those studies are usually applied to US data.

Li and Wei (2013) model the effect of QE effect in a no-arbitrage term structure model with bond supply factors. They include the par amount of outstanding bonds and average duration of private MBS holdings as supply factors in an empirical model. These supply factors influence Treasury yields through the term premium channel. The preferred-habitat literature has been further extended by studies that relate the preference of investors for particular assets to the safety of those assets. This creates a safety premium, which is part of the term premium in the bond yield. Krishnamurthy and Vissing-Jorgensen (KV, 2011) explain changes in risk spreads between lower rated corporate bonds and long-term Treasuries in the US from the supply of the latter, the safe asset. Based on single equation regressions they report that when the supply of long-term Treasuries declines due to asset purchases by the central bank, the spread between Baa and Aaa bonds rises because there are less safe assets to meet demand. This safety premium channel is effective because investors are willing to pay extra for assets with very low default risk. The channel thus predicts that QE, involving central bank purchases of risk-free bonds, lowers the yields on safe assets, with the largest effect occurring for the safest assets, with no effects on low-grade debt such as Baa bonds. This would thus imply that QE, through purchases of safe assets, increases risk spreads.

In another study (KV, 2012) Krishnamurthy and Vissing-Jorgensen show that it is the liquidity and safety attributes of Treasuries (convenience yield) that drive the yield spread between assets that differ only in terms of their safety. This relationship is tested in a regression model which relates the spread between US Treasuries and Baa rated corporate bonds to the stock of publically held government debt, next to other variables. They show that a decline of Treasury supply is associated with a rising yield spread and explain this as a change in the convenience yield of Treasuries. The convenience yield is made up by both a safety and a liquidity premium component. D'Amico et al. (2018) also relate the scarcity of safe assets to the government bond purchases by the Federal Reserve Bank (Fed). They suggest that QE increased the scarcity of sovereign bonds during the implementation period of QE.

De Negro et al. (2018) study the safety premium as driver of the natural rate of interest in a VAR model and a DSGE model. In their approach the premium is defined as a convenience yield which creates a wedge between the real interest rate and the stochastic discount factor. The existence of the convenience yield is explained by the desire of investors to hold safe and liquid bonds. Treasury bills are thus traded at a premium because they are superior to other bonds of similar maturity in terms of their safety and liquidity traits. A higher convenience yield depresses the real rate since investors are willing to accept a lower return in exchange for more convenience. The paper tests the hypothesis that, in the long run, trends in the convenience yield affect trends in the natural rate of interest.

Caballero and Farhi (CF, 2017) include safe assets in a general equilibrium model to analyze the macroeconomic implications of safe asset shortages. They show that a scarcity of safe assets, as opposed to a general shortage of assets, can be a driving force behind a deflationary safety trap equilibrium with endogenous risk premia. This outcome underpins their safe asset shortage (SAS) hypothesis, which says that a shortage of safe assets can depress economic activity. The subsequent recession lowers absolute demand for safe assets, while keeping the supply fixed and so restores equilibrium. Borio et al. (2018) criticize the SAS hypothesis, by arguing that it is more realistic to assume that equilibrium in the safe asset market is restored through portfolio adjustments than through a recession, also at the ZLB. In their view, marginal portfolio choices are driven by a widening spread between risky and safe assets, which affects safe asset demand.

Some recent studies have applied the preferred habitat approach to European data. Ferdinandusse et al. (2017) employ a search theoretic framework in which the impact of central bank asset purchases on prices is determined by the share of preferred habitat investors holding the bonds. Preferred habitat investors are also less likely to be crowded out by the central bank purchases. As a result, the impact of a QE programme on bond yields is higher in countries with a higher share of preferred habitat investors because the bonds they hold become scarce as the central bank absorbs similar assets. Three other studies relate the asset purchases by the Eurosystem to bond scarcity. Corradin and Maddaloni (2017) show that during the ECB securities market programme (SMP), the government bonds that were purchased became special, meaning that their price contained a scarcity premium. Based on high frequency German Bund data, Schlepper et al. (2017) show that ECB's asset purchases led to an increased scarcity of Bunds and this effect has increased over time. Arrata et al. (2018) find that scarcity of individual bonds of euro area countries, caused by the PSPP, has affected their specific repo rates (reflecting bond specialness). Boermans and Vermeulen (2018) also use micro data of euro area bond holdings to test whether the preferences of preferred habitat investors are time-invariant after a large policy shock. Their results show that the Eurosystem asset purchases under the PSPP did not affect the coefficients of bond demand functions among euro area investors, which suggests that investors' preferred habitat for certain bonds remained stable despite the QE program. While they do not analyze the impact on bond yields, they conclude that the preferred habitat factor may have strengthened the effects of QE purchases.

While several other empirical studies have analyzed the effect of QE on interest rates in the euro area (see ECB, 2017 for an overview), few have investigated the effect of the PSPP on sovereign bond spreads. An exception is Urbschat and Watzka (2017), who find that QE had a stronger downward effect on the spread between sovereign bond yields and the overnight index swap (OIS) rate in case of periphery countries than of core euro area countries. They suggest that the PSPP implicitly reduced the credit and liquidity premia on bonds of periphery countries, while adding the caveat that the PSPP was announced at calm times, diminishing potential effects on risk premia on core countries' bonds. The findings by Urbschat and Watzka are consistent with the expected effect of QE through the usual portfolio rebalancing channel. By changing the relative supply of assets and the composition of investment portfolios, the central bank stimulates risk-taking, by which risk premiums decline (Joyce et al, 2012). In stressed markets however, the excess liquidity may fuel demand for safe assets. The related scarcity premium is reflected in the risk-free bond yield, since bonds provide investors with cash instruments in which they can store excess liquidity. This 'store-of-value component' is not part of the OIS rate, the benchmark rate used by Urbschat and Watzka, since swaps cannot be used to store liquidity. Hence, in the euro area the yield on German government bonds is a better benchmark for estimating the effects of QE on risk premia, as we do in the next section.

The impact of QE on sovereign bond spreads in the euro area links to the paper of Bletzinger and Von Thadden (2018), who analyze the use of QE to address country specific shocks. In their theoretical model, an asymmetric shock similarly affects EMU countries with an equal financial structure ('symmetric' structures), which means that there are no structural differences in monetary transmission. Transmission works similar across countries owing to portfolio rebalancing effects that equate long-term interest rates. As a result, asset purchases according to the capital key ('symmetric QE') would be effective to respond to shocks at the ZLB. However, if EMU countries have asymmetric structures, e.g. because banks have a home bias in government bond holdings and long-term interest rates remain different across countries, 'asymmetric QE' would be effective. Asymmetric structures lead to differences in monetary transmission and this would call for asset purchases favoring the country where banks are more exposed to their own sovereign. Such QE interventions have parallels with credit easing, which also targets specific market segments. These conclusions crucially depend on the assumption in the model that the EMU is fiscally sound, so that there are no sovereign risk premia. However, this is at odds with reality. Taking into account sovereign risk, QE can have very different effects in case of asymmetric shocks and stressed markets. In those circumstances, excess liquidity created by QE can increase demand for safe assets due to risk-shedding and widen sovereign spreads. QE might then not be an effective instrument to deal with country specific shocks, as we explain in the next section.

4. Safe asset channel

4.1. Framework

In this section we present a stylized framework through which QE affects demand and supply of safe assets and sovereign bond spreads. It is inspired by Caballero and Farhi (CF, 2017), who assume that safe assets are created through the issuance of securitized assets by risk neutral investors to risk averse investors. The fraction α of risk averse investors in the total population determines the demand for safe assets. The supply of safe assets is determined by the ability of the economy to create safe assets (ρ). An adverse shock reduces this ability, thereby reducing the supply of safe assets and creating a safe asset shortage. This leads to a decline of the real safe interest rate (r_t^s) and to a risk premium between risky and safe assets. An important assumption in CF is that if $r_t^s < 0$, but the zero lower bound (ZLB) applies, a reduction of r_t^s to restore equilibrium in the safe asset market is not possible, by which risk averse investors are rationed in their demand for safe assets.

Our framework differs in several directions from CF. In our 4 period framework, a sovereign risk shock occurs in t=1, to which the central bank reacts with asset purchases at t=2. The assets are reinvested at t=3 and reinvestments end at t=4, the steady state. The framework distinguishes between banks and non-banks, supply of risky and safe assets (AS_t^r respectively AS_t^s) and between tradeable and non-tradeable safe assets. We define the supply of *tradeable* safe assets (AS_t^s) as risk-free government bonds that are liquid and marketable and are not held by the central bank. The marketability is an important feature in the analysis of the impact of QE on safe asset scarcity. Demand for safe assets (AD_t^s) is represented by government bonds held by banks (b), non-banks (nb) and the central bank (cb) and so $AD_t^s = AD_{t,b}^s + AD_{t,nb}^s + AD_{t,cb}^s$. We assume that the central bank purchases long-term government bonds, in order to reduce the term premium in the real interest rates on safe assets (r_t^s) and risky assets (r_t^r). Central bank reserves (R_t) are short-term, non-tradable safe assets, which can only be held by banks. Non-banks hold tradeable assets (AD_t) as well as commercial bank deposits (D_t), which are short-term assets, but not safe assets. All variables, except the interest rates, are one period flows.

Relative demand for tradeable safe assets (AD_t^s) and risky assets (AD_t^r) depends on the time-varying risk preference parameter α_t and structural parameter ρ (both parameters range between 0 and

1). Parameter α_t reflects the risk premium in the interest rate of risky sovereign bonds, with $\alpha_t > 0$ meaning that investors are risk averse. At t=1, we assume that α_t is determined by an exogenous shock, like in CF. Parameter ρ has a different meaning than in CF, as in our framework it represents the structural demand for tradeable safe assets, which determines portfolio choices of banks and non-banks in the steady state. Ahnert and Perotti (2018) offer an interpretation of the structural preference for safety in a theoretical model. In our framework, relative demand for tradeable safe assets (AD_t^s) and risky assets (AD_t^r) can be written as,

$$AD_t = \rho\,(1 + \alpha_t)AD_t^s + (1 - \rho)(1 - \alpha_t)AD_t^r \tag{1}$$

Equilibrium in the market of tradeable safe assets ($AD_t^s = AS_t^s$) exists if $\alpha_t = 0$, implying that relative demand for safe asset is determined by ρ, which reflects structural factors (such as capital and liquidity regulation) and/or preferred habitat demand for safe and liquid assets, which cause segmentation between safe and risky asset markets.

Parameters α and ρ, which drive relative asset demand, also determine the asset yields. The parameters cause the real interest rates on safe assets (r_t^s) and risky assets (r_t^r) to deviate from r_t^{fc}, which is defined as the real risk-free interest rate in complete markets with no arbitrage. This means that - as in the sense of the Arrow–Debreu model - there is no shortage of securities that may restrict investment strategies, while supply and demand factors do not affect bond yields and market segmentation is absent, in line with the standard no-arbitrage term structure literature.[3] The set of real interest rates is defined as,

$$r_t^r = r_t^{fc} + (1 - \rho)\,\alpha_t \tag{2}$$

$$r_t^s = r_t^{fc} - \rho - \alpha_t\rho \tag{3}$$

$$r_t^r - r_t^s = \rho + \alpha_t \tag{4}$$

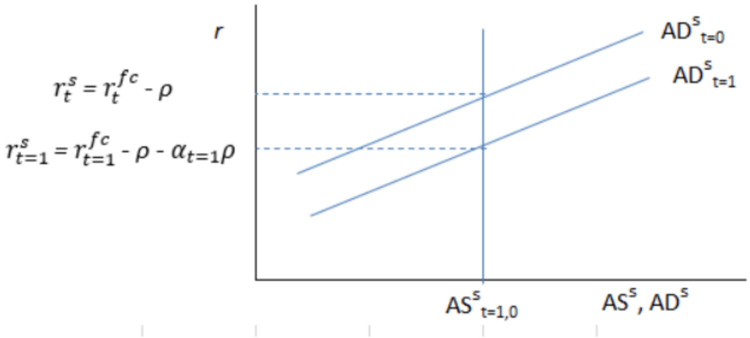
Parameter α_t in eq. (2) and (3) reflects the risk premium component in the sovereign bond yield, which after a shock partly increases r_t^r and to some extend reduces r_t^s relative to r_t^{fc} through a flight-to-safety effect. Eq. (3) says that the real interest rates on safe assets (r_t^s) equals the risk-free rate in complete markets (r_t^{fc}) minus a safety premium $\rho + \alpha_t\rho$, where ρ reflects the structural preference for tradeable safe assets. The safety premium implies that investors are willing to accept a lower interest rate on safe assets because of the store-of-value service they offer. This makes the safety premium similar to a convenience yield, defined by KV (2012) and Del Negro et al. (2018) as the premium investors are

[3] In the next section the risk-free rate in complete markets is proxied by the differences between the 10 years government bond yield of Germany and the overnight index swap rate (OIS).

willing to pay to hold safe and liquid bonds. Like in KV (2012) the safety premium has a structural (ρ) and a cyclical component ($\alpha_t \rho$), the latter reflecting a time-varying flight-to-safety effect in times of heightened risk aversion (α_t > 0). Similar to KV (2012), the yield spread between safe and risky assets in eq. (4) has two components: a risk premium and the safety premium. If risk aversion is absent (α_t = 0), parameter ρ is the sole determinant of the sovereign risk spread. We assume that the ZLB is not binding for the real interest rates to become negative. Here we also differ from CF, motivated by the practice in financial markets, which shows that interest rates on safe government bonds can fall substantially below zero owing to strong (safe haven) demand for this asset class.

At t=1 a country specific shock affects relative asset demand. When risk aversion rises ($\alpha_{t=1}$ > 0), the relative demand for safe assets increases ($AD^s_{t=1}$ > $AD^r_{t=1}$ according to eq. (1)). This flight-to-safety effect shifts the safe asset demand curve to the right (Figure 3) and reduces r^s_t by $\alpha_t \rho$ according to eq. (3). Assuming that at t=1 the amount of safe assets is in fixed supply, the additional safe asset demand changes relative asset prices and increases the spread between the interest rate on risky versus safe assets ($r^r_{t=1}$ - $r^s_{t=1}$ > 0) according to eq. (4). This adds to the structural wedge between both rates related to ρ, reflecting fundamental or structural factors that drive the sovereign yield spread.

Figure 3, Impact risk shock on safe asset market



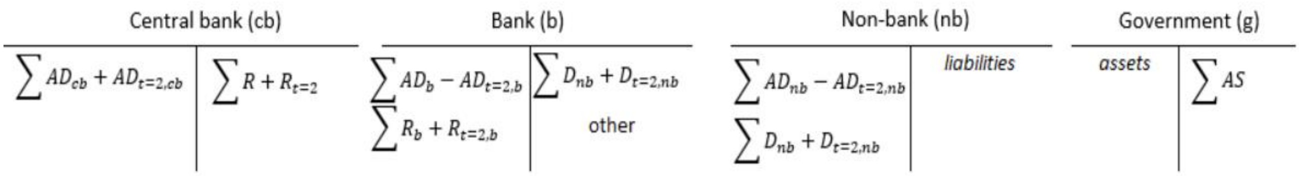
4.2. Impact of QE

At t=2, we assume that the central bank reacts to the shock by creating additional liquidity ($L_{t=2}$) with a QE programme like the PSPP. In this programme the central bank purchases both risky (AD^r_t) and safe (AD^s_t) government bonds. As a consequence, the supply of bonds that are tradeable - i.e. assets not on the balance sheet of the central bank - decreases. The bond purchases are financed by issuing central bank reserves $R_{t=2}$ to banks if the bonds are directly purchased from them. However, banks have little incentives to sell government bonds, owing to the preferential treatment of this asset class in liquidity and capital regulation (Bonner, 2016). Partly for this reason, in the PSPP non-financial euro area investors and foreign investors have been the main seller of government bonds (Boermans and Keshkov, 2018). Non-banks that sell assets to the central banks obtain a commercial bank deposit (D_t), but this is not a safe asset. The amount of liquidity in the economy is made up by both R_t and D_t (following a narrow definition of money) and so,

$$L_{t=2} = R_{t=2} + D_{t=2} \quad (5)$$

Both $\sum R$ and $\sum D$ increase owing to QE and so $\sum L$ increases as well, as depicted in Figure 4.

Figure 4, Liquidity creation by QE



The increase of liquidity can trigger portfolio rebalancing if investors are willing to take additional risk (if risk preference parameter $\alpha_{t=2} = \approx 0$). In that situation, non-banks perceive the liquidity acquired (bank deposits $D_{t=2}$) from selling assets to the central bank an imperfect substitute to higher yielding assets, such as risky government bonds (AD_t^r). Non-bank's demand for government bonds can be triggered by negative rates that banks charge on wholesale deposits. Banks are motivated to do this by the capital costs related to the excess liquidity on bank's balance sheets. Negative deposit rates encourage non-banks to search for alternative assets and so further stimulate portfolio rebalancing by them. Demand for government bonds by banks can run through the 'reserve-induced portfolio balance channel' (Christensen and Krogstrup, 2016). This channel works if banks substitute their central bank reserves ($R_{t=2}$) in higher yielding assets such as risky government bonds ($AD_{t=2}^r$), because these are more profitable.

However, the increase of liquidity can also enlarge inverse portfolio rebalancing by investors that shed risk. This is most likely in stressed market conditions (with risk preference parameter $\alpha_{t=2} > 0$). Here the impact of QE on the supply of tradeable safe assets is relevant. By purchasing safe assets from banks and non-banks and keeping those assets on the balance sheet, the central bank reduces the supply of tradeable safe assets by $AD_{t=2,cb}^s$.

$$AD_{t=2,cb}^s = (AD_{t=2,b}^s + AD_{t=2,nb}^s) \quad (6)$$

Also at t=2 we assume that $\sum AS$ does not change by the issuance of new bonds by the government (either safe or risky assets), assuming de facto that net debt issuance is zero. Furthermore, by assuming that QE reduces the supply of safe assets we differ from CF, who assume that a fall in safe asset supply relates to a diminishing ability to securitize assets. In our framework, the central bank creates safe assets in return for asset purchases by issuing central bank reserves $R_{t=2}$. However, those are only accessible for banks and are not tradeable. So on balance, QE diminishes the supply of tradeable safe assets, while it raises liquidity by $L_{t=2}$ according to eq. (5). The latter creates higher potential demand for tradeable safe assets ($AD^s_{t=2}$), most likely by non-banks, which have no access to central bank reserves. From eq. (1) it follows that relative demand for safe assets increases in stressed market conditions (when $\alpha_{t=2} > 0$). In those circumstances non-banks have a preference for risk-free government bonds, since they are special, for instance compared to commercial bank deposits (D_t), which are more risky (Diamond, 2017)[4]. By also including the effect of excess liquidity on safe asset demand and interest rates we extend the preferred-habitat literature which only focusses on the reduction of safe asset supply on bond yields.

Risk preferences may be influenced by QE, which may either lead to increased risk-taking or risk-shedding. We have no prior on the direction of this potential effect (assuming QE does not change the sign of α_t). Announcement effects may either have a downward or upward effect on risk preferences. QE announcements may lead to higher risk-taking if they lift market confidence through the signaling channel (Krishnamurthy and Vissing-Jorgensen, 2011). However, this channel may also work the other way, if announcements of new monetary policy measures feed market expectations that the central bank sees downward risks to the economy. Since the central bank purchases both risky and safe asset, the implementation effect of QE on risk preferences is neutral in principle.

The mismatch between safe asset demand and supply comes to the fore when investors prefer safe assets and shed risk ($AD^s_{t=2} > AD^r_{t=2}$), leading to a shift of the demand curve to the right in Figure 5. The additional amount of liquidity ($L_{t=2}$) created by QE thus stimulates additional safe asset demand. However, the pool of tradeable safe assets $\sum AS^s$ shrinks by $AD^s_{t=2,cb}$, being the asset purchases by the central bank, which shifts the supply curve to the left. So QE further distorts the demand and supply conditions in the safe asset market, reinforcing the effect of the risk preference shock at t=1. This relates to the preferred-habitat approach, which assumes that a decline in the stock of privately held bonds of a particular maturity creates a shortage and affects the yields of those assets, because of limited substitutability with bonds of other maturities. In the same spirit, in our framework excess demand for tradeable safe assets and their reduced supply show up in a scarcity premium in the interest rate on safe assets (r^s_t), which at t=2 can thereby further deviate from the risk-free rate in complete markets (r^{fc}_t), which is not affected by the portfolio adjustments.

$$r^s_{t=2} = r^{fc}_{t=2} - \rho - \alpha_{t=2}\rho - (\alpha_{t=2} + \rho)(L_{t=2} + AD^s_{t=2,cb}) \tag{7}$$

According to eq. (7), $r^s_{t=2}$ falls further below $r^{fc}_{t=2}$ due to a scarcity premium if $\alpha_{t=2} > 0 \lor \rho > 0 \land L_{t=2} > 0 \lor AD^s_{t=2,cb} > 0$. The scarcity premium is driven by an increased relative demand for safe assets (due

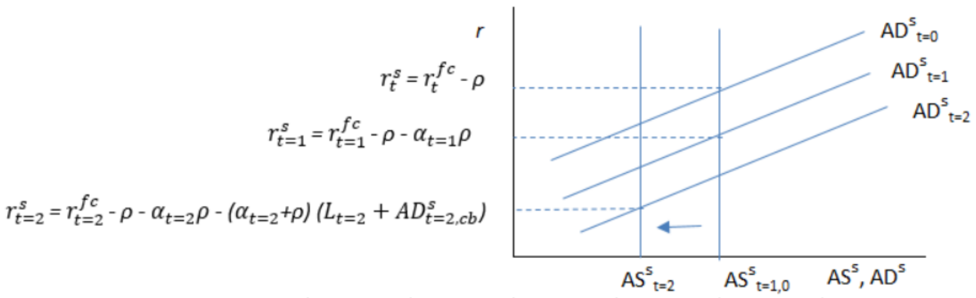
[4] In the euro area, the risk of bank deposits also depends on the resident country of the bank, given that the banking union is still incomplete.

to risk aversion α and liquidity creation as captured by $L_{t=2}$)[5] and by a reduced supply (due to central bank asset purchases $AD^{s}_{t=2,cb}$). The latter implies that preferred habitat investors, which have a time-invariant demand for safe assets, pay a higher premium for safe assets (caused by ρ in the last term of eq. (7)). This relationship is usually estimated in the preferred-habitat literature, while we add the effect of excess liquidity on the safe asset rate. In the next section we estimate to what extend the scarcity premium is time-variant, driven by stressed market conditions ($\alpha_{t=2}$) or structural (driven by ρ). Through the safe asset channel, QE further widens the spread between the safe and risky sovereign bond yield. At t=2 the sovereign bond spread equals,

$$r^{r}_{t=2} - r^{s}_{t=2} = \alpha_{t=2} + \rho\ + (\alpha_{t=2} + \rho)\ (L_{t=2} + (AD^{s}_{t=2,cb} - AD^{r}_{t=2,cb})) \tag{8}$$

The yield spread $r^{r}_{t=2} - r^{s}_{t=2}$ is composed of the risk preference effect (risk premium $\alpha_{t=2}$ and safety premium ρ) and the scarcity premium on safe assets (last term of eq. (8)). The safety and scarcity premium are both part of the term premium in the long-term bond yield. Those yield components can drive the interest rate on safe assets ($r^{s}_{t=}$) below the ZLB, assuming that investors are willing to pay a premium for holding safe assets.

Figure 5, Impact QE on safe asset market



4.3. Reinvestments

At t=3 the net asset purchases by the central bank are nil, since only the redemptions of the purchased bonds are reinvested, as illustrated in Figure 6. To redeem the bonds, the government uses its reserves at the central bank (so $\sum R$ declines[6]). The reinvestments reduce the supply of tradeable assets by $AD_{t=3,cb}$, but if the government issues a similar amount of new bonds, the stock of tradeable assets does not change. Figure 6 assumes that the new bonds are issued to banks, who extend a bank deposit to the government in return. The amount of liquidity does not change either in the reinvestment period ($L_{t=3} = -R_{t=3} + R_{t=3} = 0$).

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5 We assumes that at t=2 QE does not change the risk preferences formed at t=1 (as explained above we have no prior on the potential effect of QE on risk parameter α_t).

6 Alternatively the government could draw on its commercial bank deposits, which would reduce central bank reserves of the banks.

Figure 6, Reinvestments

Central bank (cb)		Bank (b)		Government (g)		
$\sum AD_{cb} - AD_{t=3,cb}$	$\sum R - R_{t=3}$			$\sum R - R_{t=3}$	$\sum AS_{\square} - AS_{t=3}$	redemptions
$\sum AD_{cb} + AD_{t=3,cb}$	$\sum R + R_{t=3}$	$\sum AD_b - AD_{t=3,b}$ $\sum R_b + R_{t=3,b}$				reinvestments
		$\sum AD_b + AD_{t=3,b}$	$\sum D_g + D_{t=3,g}$	$\sum D_g + D_{t=3,g}$	$\sum AS_{\square} + AS_{t=3}$	new issuance

Because in the reinvestment period $L_{t=3}$ =0, the scarcity premium in the interest rates of safe assets is determined by the stock of assets acquired by the central bank at t=2 (stock effect, mirrored by the accumulated excess liquidity $\sum L$) and by the difference between net issuance of government debt and central bank reinvestments at t=3 (flow effect). The latter implies that the sovereign spread rises if net issuance of risky assets is larger than net issuance of safe assets (both corrected for central bank purchases) and vice versa. Both the stock and flow effect are captured by the last term of eq. (9). The strength of both effects depends on risk preference parameters $\alpha_t$and ρ, which determine the sensitivity of the spread for asset supply conditions.

$$r^r_{t=3} - r^s_{t=3} = \alpha_{t=3} + \rho + (\alpha_{t=3} + \rho)\ (\textstyle\sum_t L + [(AS^r_{t=3} - AD^r_{t=3,cb}) - (AS^s_{t=3} - AD^s_{t=3,cb}]\ ) \qquad (9)$$

4.4. Steady state

At t=4 (steady state), there is no cyclical risk aversion ($\alpha_{t=4}$= 0) and QE - including reinvestments - has ended. According to eq. (1), relative demand for safe assets is then only determined by steady state parameter ρ. This parameter is then also the sole determinant of the spread between the interest rate of safe and risky assets, following from eq. (4). In the steady state, the demand for assets is fully accommodated by supply (net debt issuance by the government), so that the asset market clears and a scarcity premium is absent.

The asset market returns to equilibrium because risk preference parameter α_t - the spread between the yield of safe and risky assets - is a cyclical phenomenon. A sufficiently high level of the spread may trigger a return of risk appetite (for instance by investors with an absolute return strategy), given that the spread determines marginal portfolio choices of banks and non-banks.[7] This is in line with Borio et al. (2018) who assume that equilibrium in the safe asset market is restored through portfolio adjustments

[7] This feedback mechanism between the risk spread and risk preferences is not modelled.

that are driven by a widening spread between risky and safe assets, which affects safe asset demand. If risk aversion (α_t) declines and/or L_t decreases because reinvestments are ended, safe asset demand falls relative to risky asset demand. This restores the equilibrium in the market for tradeable safe assets. In this respect our framework differs from CF, who assume that the equilibrium is restored though the influence of a recession on safe asset demand (which in their model is unresponsive to the risk premium).

5. Empirical model

In this section we estimate the effects of QE on sovereign bond spreads of peripheral euro area countries. *SPR* is defined as the difference between the 10-years bond yield of periphery country *i* (Italy, Ireland Spain, Portugal[8], as proxy for r^r in the analytical framework) and the 10 years German bond yield (as proxy for r^s). Thereby it captures both the risk premium in the interest rate of risky bonds and the scarcity premium in the interest rate of safe bonds. Both spread components play a role in the safe asset channel, which makes *SPR* a good proxy for the effect of QE through this channel. The effect is estimated by the following panel regression model,

$$\Delta SPR_{i,t} = \beta_1 QE_t + \beta_2 MP_t + \beta_3\, \Delta BAL_t + \; \beta_4 \Delta DEBT_{i,t} + \; \beta_5 \Delta\, NEWS_t \; + \beta_6 \Delta X_{i,t} + \lambda_{i,t} + \varepsilon_{i,t}$$

QE is a dummy that equals 1 on days at which an adjustment of the PSPP programme was announced, such as an adjustment of the monthly purchase amounts or an extension of the horizon of the programme (otherwise dummy=0). Variable QE captures the expected impact of central bank asset purchases on bond supply, similar to $AD_{t,cb}$ in eq. (7)-(9). Other studies use the stock of outstanding bonds as supply factors in regression models (for instance Li and Wei, 2013, VK, 2012), which measures the implementation effect of QE, rather than the announcement effect. We think the announcement effect better captures market expectations about the impact of QE on the stock of tradeable bonds.

The sample includes five events (*QE*=1), one being the announcement of the introduction of the PSPP in January 2015 and four being announcements on extensions of the PSPP period (one was combined with an increase of the monthly purchases and two with a decrease of the monthly purchases; the announcements concerned different amounts of purchases). A positive sign of *QE* indicates that PSPP announcements is associated with rising sovereign spreads, possibly because it enlarges the effect of risk-shedding if risk aversion is high. Figure 7 shows the QE announcement dates, as well as proxies for the risk premium and the scarcity premium components in the sovereign bond yields.

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8 Greece is excluded because Greek bonds were not eligible for the PSPP programme.

Figure 7. QE announcements and yield components

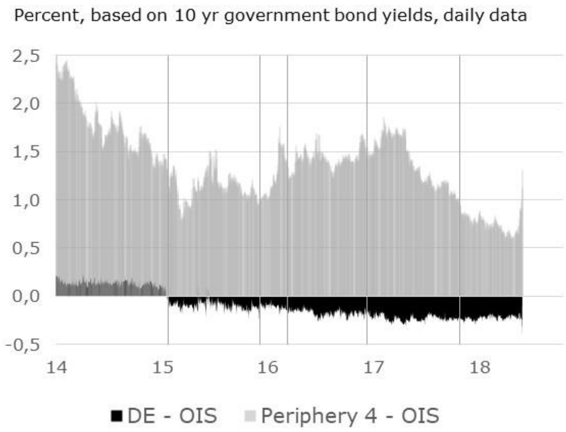
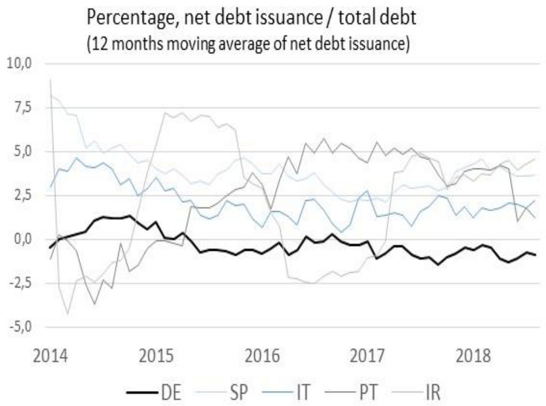


Figure 8. Net debt issuance



Note: in Figure 7, QE announcement dates are represented by the vertical lines. DE - OIS is the differences between the 10 years government bond yield of Germany and the overnight index swap rate (OIS), as proxy of the scarcity premium. Periphery 4 - OIS is the differences between the (unweighted average)10 years government bond yield of Italy, Ireland, Spain and Portugal and the overnight index swap rate (OIS), as proxy of the risk premium. The OIS rate is a measure of the risk-free interest rate in complete markets.

In the regression model, variable *MP* is a dummy that equals 1 on a day at which changes in other monetary policy instruments were announced, such as in private asset purchase programs, long-term refinancing operations (LTROs) or the policy rate (otherwise dummy=0). By this we control for the effect of monetary policy measures other than QE, which in the sample period were all measures to loosen monetary conditions (so *MP* = 1 means monetary policy is loosened).

Excess liquidity is captured by variable *BAL*, which is defined as the relative change of the Eurosystem balance sheet total. *BAL* is a proxy for liquidity in the economy injected through central bank asset purchases (similar to L_t in the analytical framework). It includes central bank reserves held by banks and thereby *BAL* is also an indirect measure of bank deposits held by non-banks. If they sell bonds in an asset purchase program, they get a bank deposit in return, while the bank that settles the transaction with the central bank increases its reserve position. So central bank reserves indirectly measure the increase of liquidity of non-banks. A more direct measure of non-bank liquidity would be non-bank deposit holdings at banks, which in the euro area is part of the broad monetary aggregate M3. However, this measure not only captures the liquidity obtained through assets sales, but also any other transaction which changes the deposits of non-banks. This makes bank deposits held by non-banks an imperfect measure of liquidity related to QE.[9] Moreover, this measure is only available on a monthly basis, while the Eurosystem balance sheet total (variable *BAL*) is available on a weekly basis. For these reasons we took the latter as proxy for excess liquidity.

Variable *DEBT* captures the net issuance of government debt relative to Germany, in which the

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[9] The correlation between the relative change of the Eurosystem balance sheet total and the relative change of non-bank deposits (included in M3) is low (0.09 over the sample period).

effect of central bank purchases is not included. It is defined as the net issuance of sovereign debt by country *i* over total debt of country *i* minus net issuance of debt by Germany over total debt of Germany. Figure 8 indicates that most of the time this variable is positive for the four peripheral countries, given that net issuance of government debt by Germany is relatively lower and frequently negative. This suggests that variable *DEBT* on average will have an upward effect on sovereign bond spreads through the scarcity premium of safe assets. Vector *X* contains a set of control variables, in particular the CDS bank index in country *i* (*CDS*), 5y/5y forward inflation expectations *INF*, the VST index. Variable *VST* is a measure of market stress in the euro area, as reflected by the implied volatility of the stock market index VSTOXX.[10] This measure reflects the degree of risk aversion in financial markets, similar to risk preference parameter α_t in the analytical framework. Thereby the variables in vector *X* control for various components of sovereign bond spreads that are not directly linked to QE.

Since QE announcements or the anticipation of monetary policy measures (variable *NEWS*) may influence risk aversion or the other control variables, we tested for multicollinearity. This does not seem to be an issue, as indicated by the low variance inflation factors (see Annex 1). We include country-time fixed effects ($\lambda_{i,t}$) to control for unobserved time-variant country characteristics that capture all macroeconomic conditions at the country level that could be impacting sovereign spreads. Country characteristics may reflect preferences for particular assets and thereby also may capture elements of the safety premium in the yield of safe assets.

To test the assumption in the analytical framework that the safe asset channel is associated with stressed market conditions, we distinguish normal from stressed market conditions by two methods. The first method splits the sample in periods in which the VST index is below 20 (quiet market conditions) and periods in which the index is above 20 (volatile markets). The value of 20 roughly splits the sample in two equally long time spans. The drawback of the split sample regression is that the estimated coefficients differ per sub-sample, which complicates a comparison of the results between both sub-samples. The second method includes variable *VST* as a dummy in the interaction with variable *BAL* and as separate control variable. The dummy equals 1 on days at which the VSTOXX index is higher than 20 (volatile markets) and 0 if the VSTOXX index is below 20 (quiet markets).

In our model, endogeneity can be an issue, since monetary policy may not only influence sovereign spreads, but it may be responding to them as well. So to identify the effect of changes in the monetary policy variables (*QE*, *MP*, *BAL*), they should be surprise shocks that are relatively free from endogenous and anticipatory effects. To ensure that monetary policy changes are not taken in response to market expectations (an ex-ante available variable that may or may not be taken into account in monetary policy) we control for anticipation effects. These are captured by a news variable, being the relative frequency of Bloomberg news items about the QE policy of the Eurosystem, as a proxy for the

[10] VST is the VSTOXX Index, which based on the EURO STOXX 50 real-time options prices and reflect the market expectations of near-term up to long-term volatility by measuring the square root of the implied variance across all options of a given time to expiration.

anticipation on changes in the asset purchase programme by market participants. The news variable is constructed by the proportion of Bloomberg news articles containing the terms 'QE', 'quantitative easing', 'sovereign', alongside the key words 'euro area', 'ECB', or 'Draghi'. A similar variable is used to control for anticipation effects by Middeldorp and Wood (2016) and Urbschat and Watzka (2017). Next to controlling for anticipation effects, the endogeneity problem is addressed by a timing restriction. While monetary policy changes (variables *QE* and *MP*) are always announced by the ECB early afternoon, the spread variable (*SPR*) is an end of the day data point. This time difference helps to ensure that monetary policy does not react contemporaneously to changes in sovereign spreads.

The model is estimated for the period 2014-May 2018, based on daily observations (Annex 2 provides summary statistics of the data). By starting the sample in 2014, it includes the anticipation effects on financial market prices related to the PSPP, which was activated early 2015. Here we deviate from event studies, in which the estimations are usually based on a very short event window of several days. Estimating our model over such a short window would leave too little degrees of freedom given the limited number of countries. All variables, except the dummies are included in first differences (daily changes; given that most variables have a unit root (Annex 3). Variable *BAL* is included in terms of week-on-week changes and *DEBT* in monthly changes (because a higher frequency of these series is not available). The model is estimated using OLS with robust standard errors (to control for heteroskedasticity and autocorrelation).

6. Outcomes

The model is first estimated for two sub-periods; one of quiet market conditions (VST below 20) and one of volatile markets (VST above 20). The R2 statistics indicate that the model best fits the latter sub-sample (compare R2 in Tables 1 and 2). Secondly, we distinguish volatile from quiet periods by estimating the model with variable *VST* as a dummy in the interaction with variable *BAL* (last column of Table 2). The outcomes of both methods are almost similar. They show that in both sub-samples the QE announcements had a significant upward effect on sovereign bond spreads. This indicates that since 2014, QE announcements have enlarged the effects of risk-shedding, confirming the postulate in the analytical framework. The estimated coefficient of variable *NEWS* is significantly negative in both periods and also in the VST dummy variant. This indicates that anticipation effects had a downward effect on sovereign spreads on average, which may be the result of portfolio rebalancing. The difference between the sign of the coefficients of *QE* and *NEWS* suggests that the increased risk-taking in anticipation of QE was replaced after the announcement by risk-shedding.

In both sub-samples the coefficient of variable *BAL* is significant with a positive sign. This indicates that increasing excess liquidity adds to a widening yield spread between peripheral and German bonds. In stressed market conditions, the coefficient of variable *BAL* is higher than in quiet markets, which suggests that increasing liquidity has a stronger effect on bond spreads in stressed markets. The change of yield spreads in response to a change in *BAL* is substantial in an economic sense. If ratio *BAL* increases (decreases) by 1 percentage point (which is less than the standard deviation of ΔBAL), *SPR* rises (falls) by 9 basis points in quiet times and by 32 basis points in stressed markets, which is more than 1, respectively 5 times the standard deviation of ΔSPR. If variable *VST* is included as a dummy in the interaction with variable *BAL* (second method to distinguish volatile from quiet periods), the coefficients of both variable *BAL* and the interaction term *BAL*VST* also have a significant positive sign (last column of Table 2). All in all the outcomes suggest that bond spreads widen due to additional safe asset demand, which is spurred by excess liquidity. The widening of bond spreads may be associated with a rising scarcity premium in the interest rate of safe assets. The effect on sovereign spreads is strongest in stressed market conditions, suggesting that it is more likely a cyclical than a structural phenomenon (implying that in stressed markets the effect of α outpaces the effect of ρ in eq. (8)). It underlines that the excess liquidity enlarges the leakage effect of QE to safety if risk-aversion is high.

It is striking that other monetary policy measures (variable *MP*) had a significant downward effect on sovereign spreads, in both sub-samples as well as in the method with the VST dummy.[11] This indicates that the monetary policy measures other than QE, such as credit easing measures and policy rate cuts, contributed to lower sovereign risk spreads during the sample period. The coefficient of variable *DEBT* is mostly not significant, but when it is significant it has a positive sign. This is in line with the assumed positive relation in eq. (9) between the net issuance of government debt of country *i* relative to Germany (the safe country) and the sovereign spread.

Model estimations by individual country show that the QE announcement effect is driven by Portugal in quiet periods (Table 1) and by Italy and Spain in stress periods (Table 2), given the significant positive coefficient of the QE dummy in those countries. The coefficient of variable *BAL* is positive and significant in nearly all countries in both sub-samples. This confirms the outcomes of the panel regressions.

[11] Gilbert & Kho (2017) find that German and Italian bond yields had reacted more homogeneous since 2013 in response to ECB-announcements than before. Their findings are hard to compare with our results, since they do not distinguish different monetary policy measures.

Table 1. Regression outcomes for quiet market conditions ($\Delta\, SPR$ is dependent variable)

	VST < 20				
	Sample	***IT***	***ES***	***PT***	***IR***
QE_t	0.05**	0.06	0.02	0.12*	0.01
	(0.02)	(0.04)	(0.03)	(0.07)	(0.01)
MP_t	-0.05***	-0.06**	-0.05	-0.01	-0.05***
	(0.01)	(0.03)	(0.04)	(0.03)	(0.01)
$\Delta\, NEWS_t$	-0.03**	-0.05	0.01	-0.03	-0.03
	(0.01)	(0.05)	(0.05)	(0.07)	(0.05)
$\Delta\, BAL_t$	0.09***	-0.44**	0.09***	0.14***	0.04***
	(0.03)	(0.19)	(0.03)	(0.03)	(0.01)
$\Delta\, DEBT_t$	0.66	-0.18	1.18	0.13	1.36***
	(0.44)	(1.12)	(1.00)	(0.72)	(0.44)
Country time FE	yes	no	no	no	no
Obs	2052	514	514	514	514
R^2	0.13	0.20	0.18	0.14	0.04

Sample period Jan. 2014 - May 2018. Based on OLS with robust standard errors. Coefficients control variables in vector $X_{i,t}$ are not reported. Variable $\Delta\, NEWS$ is scaled, see Annex 1. ***, **, * significance at 1%, 5%, 10% confidence level. Standard errors between brackets.

Table 2. Regression outcomes for volatile market conditions ($\Delta\, SPR$ is dependent variable)

	VST > 20					***VST dummy***
	Sample 1	***IT***	***ES***	***PT***	***IR***	***Sample 2***
QE_t	0.03***	0.05**	0.05**	0.04	0.01	0.04***
	(0.01)	(0.02)	(0.02)	(0.04)	(0.02)	(0.01)
MP_t	-0.02***	-0.01	0.01	-0.03	-0.01**	-0.04***
	(0.01)	(0.01)	(0.02)	(0.03)	(0.01)	(0.01)
$\Delta\, NEWS_t$	-0.12**	-0.17*	-0.19**	-0.15	-0.00	-0.09***
	(0.04)	(0.09)	(0.08)	(0.16)	(0.06)	(0.02)
$\Delta\, BAL_t$	0.32***	0.21	0.26*	0.50**	0.25**	0.09***
	(0.06)	(0.16)	(0.15)	(0.25)	(0.11)	(0.02)
$\Delta\, DEBT_t$	-0.06	-0.81	-2.51	0.18	0.19	0.35*
	(0.43)	(0.94)	(2.17)	(0.57)	(0.72)	(0.21)
$\Delta\, BAL_t * VST$						0.18***
						(0.03)
Country time FE	yes	no	no	no	no	yes
Obs	1596	399	399	399	399	3648
R^2	0.25	0.27	0.36	0.27	0.16	0.13

Sample period Jan. 2014 - May 2018. Based on OLS with robust standard errors. Coefficients control variables in vector $X_{i,t}$ not reported. In sample 1 variable VST is included in first differences; in sample 2 variable VST is a dummy. Variable $\Delta\, NEWS$ is scaled, see Annex 1. ***, **, * significance at 1%, 5%, 10% confidence level. Standard errors between brackets.

7. Robustness checks

As robustness check the model is also estimated with changes in *SPR* over 3, 5 and 10 days forward, to assess the persistence in the changes of the spreads (Annex 4). The outcomes show that in those specifications, the coefficient of variable *QE* is significantly negative. This contrasts to the significant positive coefficient in the original model specification (with the non-cumulative *SPR* variable). However, anticipation effects, captured by variable *NEWS*, are in most cases significantly positive in the model with spread changes 3, 5 and 10 days forward, in contrast to the negative coefficient of *NEWS* in the original model specification. These outcomes suggest that the information contained in QE announcements had a similar effect on forward spread changes as *NEWS* had on 1 day ahead spread changes. This may result from the time lag between QE announcements and forward spread changes, which makes that the anticipation effect is picked up by announcements (and not by news) in the model with forward changes of spreads. This complicates the identification of the pure announcement effect in the model with forward spread changes as dependent variable. In almost all cases variable *BAL* has a significant positive coefficient with cumulative changes in *SPR*, like in the model with the non-cumulative *SPR* variable.

As another robust check we include sovereign spreads based on other maturities, in particular on government bonds with a maturity of 3 months and 1 year (Annex 5). In the regression outcomes based on these maturities, the coefficient of *QE* is (in one case significantly) negative. This contrasts to the significant positive *QE* coefficient in the regression based on 10 years maturities. A possible explanation for this difference is that short-term peripheral bonds may be perceived as safer than long-term bonds, by which excess liquidity more likely flows to short-term than long-term peripheral bonds. As a result, the spread on short-term government bonds does not widen but narrows. The coefficients of variable *BAL* based on the regression with short-term maturities is in most cases significant with a positive sign, like in the model based on 10 year bonds. However, the significance levels are somewhat lower and this might be related to the remaining weighted average maturity of the PSPP portfolio, which is over 7.5 years, matching the maturity of the 10 years government bond yields better than short maturities. This makes it likely that the liquidity acquired by selling long-term bonds is re-invested in bonds with similar maturities, given that investors are inclined to maintain the duration of their portfolio. This implies that portfolio rebalancing effects are most likely in long-term segments of the government bond market. Having said this, the coefficients of variable *BAL* in the regression with 3 months and 1 year maturities are larger for stress periods than quiet periods, similar to the outcomes of the 10 years maturities. This confirms that risk-shedding, enlarged by excess liquidity, is most likely in stressful market conditions.

In the last robustness test, the QE dummy excludes the two announcements which were combined with a decrease of the monthly purchases. The outcomes show that the results are similar to the outcomes including the original QE dummy (Annex 6). Both in quiet and in stressed market conditions the coefficient of the QE dummy is significantly positive and the same holds for variable *BAL*. The coefficient of the latter is also higher in stressed than in quiet conditions, indicating that the effects of excess liquidity on sovereign spreads is enlarged in stressful markets through the safe asset channel.

8. Conclusion

Outcomes of a regression model based on data of euro area countries show evidence for the safe asset channel. Through this channel, the excess liquidity created by QE stimulates investor demand for tradeable safe assets. This demand mainly comes from non-banks, which have no access to central bank reserves and so buy risk-free government bonds as an alternative. So they incite the safe asset channel. The additional safe asset demand goes with risk-shedding and a widening of risk spreads in sovereign bond markets, as the yield on safe bonds falls relative to the yield on risky bonds. This effect is most likely in stressed markets, when the preference for safe assets is high. The spread effect is exacerbated by a reduced supply of tradeable safe assets due to central bank purchases of this asset class in a QE programme.

Over the whole sample period the safe asset channel (through risk-shedding) seems to dominate the usual portfolio rebalancing channel, since on average QE announcements and the change of liquidity are associated with higher sovereign bond spreads. In contrast to that, anticipation effects had a downward effect on sovereign spreads on average, which may be the result of increased risk-taking. The different directional effect of announcement and anticipation effects on sovereign spreads suggest that risk-taking in anticipation of QE was replaced after the announcement by risk-shedding.

The outcomes of the empirical analysis suggest that symmetric QE (the current design in the euro area) is not effective in lowering risk spreads in the case of country specific shocks. This was also not the intended effect of QE, as conducted by the Eurosystem. Instead, QE has loosened financial conditions by lowering interest rates, although less so for risky than for safe assets in line with the safe asset channel. This leakage effect to safety is enlarged if risk-aversion is high. By raising sovereign spreads, the full transmission of monetary policy across the whole risk spectrum is limited. A widening of sovereign bond spreads in the EMU affects marginal investments and the allocation of capital in the economy and would add to an uneven transmission of monetary policy across countries.

To address asymmetric shocks in individual countries with QE, an alternative is to change the composition of the bond purchases from the capital key to market capitalization, or another benchmark that concentrates the asset purchases on risky countries. However, this might neither be effective to address sovereign risk, since any form of (unsterilized) QE goes with increasing excess liquidity, which - as an indirect effect in volatile market conditions - will flow to safe assets and so raise sovereign bond spreads in the euro area. This makes QE an inappropriate instrument to deal with country specific shocks.

References

Ahnert, T & E. Perotti (2018), Seeking Safety, Bank of Canada working paper, 41.

Arrata, W, B. Nguyen, I. Rahmouni-Rousseau & M. Vari (2018), The Scarcity Effect of Quantitative Easing on Repo Rates: Evidence from the Euro Area, IMF working paper, 18/258.

Beetsma, R., De Jong, F., Giuliodori, M. & D. Widijanto (2014), The impact of news and the SMP on realized (co)variances in the Eurozone sovereign debt market, ECB Working Paper, 1629.

Bletzinger, T. & L. von Thadden (2018), Designing QE in a fiscally sound monetary union, ECB working paper 2156.

Boermans, M. & R. Vermeulen (2018), Quantitative easing and preferred habitat investors in the euro area bond market, DNB Working Paper 586.

Boermans, M. & A., Keshkov, V. (2018), The impact of the ECB asset purchases on the European bond market structure: Granular evidence on ownership concentration, DNB Working Paper, 590.

Bonner, C. (2016), Preferential Regulatory Treatment and Banks' Demand for Government Bonds, Journal of Money, Credit and Banking, 48(6), 1195-1221.

Borio, C., P. Disyatat & P. Rungcharoenkitkul (2018), What anchors for the natural rate of interest?, paper prepared for the Federal Reserve Bank of Boston 62nd Annual Conference, 7-8 September 2018, Boston.

Caballero, R. J. & E. Farhi (2017), The safety trap, Review of Economic Studies, 0, 1-52.

Christensen, J.H.E. & S. Krogstrup (2016), A Portfolio Model of Quantitative Easing, Working Paper 16-7, Peterson Institute for International Economics.

Corradin, S. & A. Maddaloni (2017), The importance of being special: Repo markets during the crisis, ECB Working Paper, 2065.

D'Amico, S., Fan, R. & Kitsul, Y. (2018), The scarcity value of treasury collateral: Repo market effects of security-specific supply and demand factors, Journal of Financial and Quantitative Analysis, 53(5), p. 2103-2129.

Del Negro, M., Giannone, D., Giannoni, M. & A. Tambalotti (2018), Global trends in interest rates, Staff Reports 866, Federal Reserve Bank of New York.

Diamond, W. (2017), Safety transformation and the structure of the financial system, mimeo.

Draghi, M. (2018), press conference, Riga, 14 June 2018.

ECB (2014), The determinants of euro area sovereign bond yield spreads during the crisis, Monthly Bulletin, May 2014, 67-83.

ECB (2017), Impact of the ECB's non-standard measures on financing conditions: taking stock of recent evidence, ECB Economic Bulletin, 2, 46-51.

Ferdinandusse, M., Freier, M. & Ristiniemi, A. (2017), Quantitative easing and the price-liquidity trade-off, ECB Working Paper 2021.

Gilbert. N. & S. Kho (2017), Rente-verrassingen rond ECB-besluiten: hoe homogeen is de Europese monetaire beleidsimpuls?, DNB mimeo.

Golec, P & E. Perotti (2017), Safe assets: A review, ECB Working Paper, 2035.

Grandia, R. P. Hänling, M. Lo Russo and P. Åberg (2019), Availability of high-quality liquid assets and monetary policy operations: an analysis for the euro area, ECB Occasional Paper, 218.

Joyce, M., D. Miles, A. Scott & D. Vayanos (2012), Quantitative Easing and Unconventional Monetary Policy – an Introduction, The Economic Journal, 122(564), 271-288.

Krishnamurthy, A. & A. Vissing-Jorgensen (2011), The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy, NBER Working Paper, 17555.

Krishnamurthy, A. & A. Vissing-Jorgensen (2012), The Aggregate Demand for Treasury Debt, Journal of Political Economy, 120, 233-267.

Li, C. & M. Wei (2013), Term Structure Modeling with Supply Factor and the Federal Reserve's Large-Scale Asset Purchase Programs, International Journal of Central Banking, 9(1), 3-39.

Middeldorp, M. & O. Wood (2016), Too eagerly anticipated: The impact of the extension of ECB QE on asset prices, Bank of England blog, 4 March 2016.

Modigliani, F. & R. Sutch (1966), Innovations in Interest Rate Policy, American Economic Review 56 (1/2), 178–97.

Modigliani, F. & R. Sutch (1967), Debt Management and the Term Structure of Interest Rates: An Empirical Analysis of Recent Experience." Journal of Political Economy 75(4/2): Issues in Monetary Research), 569–89.

Schlepper, K., R. Riordan, H. Hofer & A. Schrimpf (2017), Scarcity effects of QE: A transaction-level analysis in the Bund market, BIS Working Paper, 625.

Urbschat, F. & S. Watzka (2017), Quantitative Easing in the Euro Area - An Event Study Approach, CESifo Working Paper, 6709.

Annex 1. *Variance Inflation Factors (VIF)*

Variable	VIF
QE	1.32
MP	1.09
Δ NEWS	1.31
Δ BAL	1.00
Δ VST	1.13
Δ INF	1.06
Δ CDS	1.10
Δ DEBT	1.00

VIF based on the regression model presented in section 5.

Annex 2. *Summary statistics, January 2014 – May 2018*

	All countries (*IT, ES, PT, IR*)		
	Mean	Median	St. dev.
Main variables			
Δ SPR	0.002	0.000	0.063
Δ NEWS	-0.000	0.001	0.036
Δ BAL	-0.002	0.000	0.053
Δ VST	0.150	0.030	2.033
Control variables			
Δ INF	-0.001	0.000	0.021
Δ CDS	0.424	0.005	5.992
Δ DEBT	0.029	0.033	0.027

Note: dummy variables (*QE*, *MP*) not included. Variable *NEWS* is scaled by 1,000.

Annex 3. *Fisher type unit-root tests (based on augmented Dickey-Fuller tests)*

Ho: Panels contain unit roots
Ha: Panels are stationary

Time trend:	Not included		Included	
Variable	Chi^2 stat.	p-value	Chi^2 stat.	p-value
SPR	8.89	0.35	2.81	0.95
NEWS	0.99	1.00	0.14	1.00
BAL	0.00	1.00	0.00	1.00
VST	30.1	0.00	20.6	0.01
INF	19.1	0.01	13.0	0.11
CDS	7.19	0.52	3.70	0.88
DEBT	5.39	0.71	1.66	0.99

ADF regressions: 1 lag.

Annex 4. *Regression outcomes for cumulative changes in SPR ($\Delta\, SPR$ is dependent variable)*

	Sample					
	VST < 20			***VST > 20***		
Horizon	***3 days***	***5 days***	***10 days***	***3 days***	***5 days***	***10 days***
QE_t	-0.03	-0.04**	-0.08**	-0.05***	-0.08***	-0.17***
	(0.02)	(0.02)	(0.04)	(0.01)	(0.02)	(0.02)
MP_t	-0.09***	-0.08**	-0.14***	-0.00	0.06	-0.08
	(0.01)	(0.03)	(0.05)	(0.02)	(0.04)	(0.06)
$\Delta\, NEWS_t$	0.05**	-0.05	0.05	0.08**	0.05*	0.18***
	(0.02)	(0.04)	(0.04)	(0.04)	(0.03)	(0.06)
$\Delta\, BAL_t$	0.14***	0.18**	0.27*	0.13***	0.30**	-1.23***
	(0.04)	(0.07)	(0.15)	(0.05)	(0.14)	(0.23)
$\Delta\, DEBT_t$	1.76***	2.17	3.99**	-3.58***	-4.13*	-4.04**
	(0.41)	(1.40)	(1.97)	(1.23)	(2.12)	(2.00)
Country time FE	yes	yes	yes	yes	yes	yes
Obs	2046	2043	2040	1596	1596	1596
R^2	0.08	0.05	0.04	0.13	0.08	0.06

Sample period Jan. 2014 - May 2018. Based on OLS with robust standard errors. Coefficients control variables in vector $X_{i,t}$ are not reported. Variable $\Delta NEWS$ is scaled, see Annex 1. ***, **, * significance at 1%, 5%, 10% confidence level. Standard errors between brackets.

Annex 5. *Regression outcomes for other government bond maturities ($\Delta\ SPR$ is dependent variable)*

	Sample					
	VST < 20			***VST > 20***		
Maturity	***3 mt***	***1 yr***	***10 yr***	***3 mt***	***1 yr***	***10 yr***
QE_t	-0.06	-0.00	0.05***	-0.02	-0.07***	0.03***
	(0.08)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
MP_t	0.09	-0.06**	-0.05***	0.02*	0.02	-0.02***
	(0.08)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
$\Delta\ NEWS_t$	0.05***	0.04***	-0.03***	0.03*	0.05	-0.12**
	(0.02)	(0.02)	(0.01)	(0.02)	(0.04)	(0.04)
$\Delta\ BAL_t$	-0.10	0.03***	0.09***	0.53	0.09**	0.32***
	(0.15)	(0.02)	(0.03)	(0.35)	(0.04)	(0.06)
$\Delta\ DEBT_t$	4.82	0.81	0.66	-2.26	-0.47***	-0.06
	(6.22)	(0.02)	(0.44)	(3.83)	(0.16)	(0.43)
Country time FE	yes	yes	yes	yes	yes	yes
Obs	2052	2052	2052	1596	1596	1596
R^2	0.01	0.04	0.13	0.00	0.04	0.25

Sample period Jan. 2014 - May 2018. Based on OLS with robust standard errors. Coefficients control variables in vector $X_{i,t}$ are not reported. Variable $\Delta NEWS$ is scaled, see Annex 1. ***, **, * significance at 1%, 5%, 10% confidence level. Standard errors between brackets.

Annex 6. *Regression outcomes with QE announcement dummy excluding reductions of purchases*

	Sample		
	Full sample	***VST > 20***	***VST dummy***
QE_t	0.04***	0.03***	0.02**
	(0.01)	(0.01)	(0.01)
MP_t	-0.04***	-0.02***	-0.03***
	(0.01)	(0.01)	(0.01)
$\Delta\ NEWS_t$	-0.06***	-0.12***	-0.06***
	(0.02)	(0.04)	(0.01)
$\Delta\ BAL_t$	0.10***	0.32***	0.08***
	(0.03)	(0.06)	(0.02)
$\Delta\ DEBT_t$	0.29	-0.06	0.36*
	(0.29)	(0.42)	(0.02)
$\Delta\ BAL_t * VST$			0.19***
			(0.04)
Country time FE	yes	yes	yes
Obs	3648	1596	3648
R^2	0.19	0.25	0.13

Sample period Jan. 2014 - May 2018. Based on OLS with robust standard errors. Coefficients control variables in vector $X_{i,t}$ are not reported. Variable $\Delta NEWS$ is scaled, see Annex 1. ***, **, * significance at 1%, 5%, 10% confidence level. Standard errors between brackets.

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De Nederlandsche Bank N.V.
Postbus 98, 1000 AB Amsterdam
020 524 91 11
dnb.nl