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Spillover Effects of Sovereign Debt-Based Quantitative Easing in the Euro Area

December 2021

Matthias Gnewuch
Research Area D: Inequality and macroeconomic policies

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ABSTRACT

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Abstract

This paper proposes an identification strategy for news about sovereign debt-based asset purchases. It measures sovereign yield changes that are unrelated to movements in risk-free interest rates or risk premiums. Around ECB announcements, these reflect the anticipation of shifts in the effective supply of government debt, caused by central bank purchases. This paper documents that asset purchase news about government bonds have substantial spillovers to corporate bond and stock markets, within and beyond the euro area. Spillovers are unequal across euro-area countries, as stock prices rise most in low-risk countries with very large firms. In contrast, sovereign yields fall homogeneously.

Keywords: quantitative easing, high-frequency identification, euro area heterogeneity, ECB, PSPP, bond scarcity

JEL Codes: E58, E52, G12

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1 Introduction

Since the Great Recession, central banks around the world have introduced large-scale asset purchase programs to provide stimulus to economies at or near the Effective Lower Bound (ELB). Initially, these programs were considered to be exceptional and temporary, hence the label *unconventional* monetary policy. Yet, central bank balance sheets have remained at elevated levels and again rose sharply in the wake of the COVID-19 crisis. It thus appears that asset purchase programs have become part of the toolkit of regular central bank policy. In light of this, it is of first-order importance to understand the effects and transmission mechanisms of asset purchases. This is an intricate task, because asset purchases are employed in view of economic conditions and oftentimes announced jointly with other policy measures. Thus, to understand the causal effects of asset purchases, one has to account for the endogeneity of asset purchases to economic conditions and for concurrent policy announcements.

In this paper, I propose a novel strategy to identify the effects of central bank purchases of government debt, henceforth "asset purchases", which accounts for these concerns. It is well-known that monetary policy decisions affect many financial variables, including government bond yields, risk-free interest rates and risk premiums. Movements in none of these variables, around policy communication events, are guaranteed to arise from news about asset purchases only. The fundamental idea is that long-term government bond yields, instead, include a component that can be argued to reflect only news about asset purchases. I measure this component, which I label the "scarcity premium", as the government bond yield in excess of the risk-free interest rate and the risk premium. This component arises due to the particular structure of the market for long-term government debt. Namely, the demand for long-term government debt is rather inelastic because there exists a unique clientele for long-term, safe nominal assets (Krishnamurthy and Vissing-Jorgensen, 2011). At the same time, the supply of debt by governments is limited and relatively inelastic in the short to medium term, as well. In this market environment, central bank asset purchases reduce the effective supply of government debt available to the public and, thus, affect the scarcity premium. I, then, use movements in the scarcity premium around ECB policy com-

munication events to measure the effects of news about asset purchases. I find that asset purchases reduce euro-area sovereign bond yields rather homogeneously. Thus, I do not find that sovereign yield spreads of other countries vis-à-vis Germany fall significantly. At the same time, asset purchases increase stock prices; the effect being largest in Germany, France, and the Netherlands, i.e. countries with relatively few concerns about sovereign solvency. These two pieces of evidence may raise doubts about the prevalent view that asset purchases mostly benefit highly indebted countries.[1]

More in detail, the identification strategy developed in this paper builds on high-frequency identification. By looking at changes in monetary policy expectations in a narrow window around official central bank communication, we can identify the unexpected component of policy decisions. This deals with the endogeneity of policy decisions to economic conditions. To measure the change in expectations about asset purchases, changes in long-term interest rates, such as government bond yields, are commonly used. However, because multiple policy decisions are typically announced jointly, changes in long-term interest rates reflect not only news about asset purchases, but also news about other monetary policy measures and information about the state of the economy. The latter, Jarociński and Karadi (2020) show how to distinguish from interest rate movements due to monetary policy. Altavilla et al. (2019), on whose work I build and whose database I use, highlight that it is important to separate the different monetary policy measures which move interest rates. Thus, ideally, we would want to distinguish news about asset purchases from both, news about other policy measures and information about the state of the economy. For this purpose, I decompose long-term government bond yields of several euro-area countries into the risk-free interest rate, a risk premium, and the scarcity premium. Changes in the risk-free interest rate or the risk premium can reflect various monetary policy measures as well as the revelation of information. In contrast, changes in the scarcity premium can be argued to reflect only news about asset purchases. The supply by governments being inelastic, asset purchases reduce the effective supply of government debt available to the public. Demand

[1]For example, *The Economist* wrote "A fear often heard in the northern countries of the currency bloc [...] is that QE, by lowering the financing costs of indebted southern governments, allows them to avoid painful reforms. It is true that loose money has benefited highly indebted countries the most." (The Economist, October 10, 2019, "What to make of the strife at the ECB")

also being inelastic, purchases reduce sovereign yields over and above any effect on the risk-free interest rate or the risk premium: the scarcity premium moves. At the same time, other monetary policy measures and information about the state of the economy do not significantly affect supply and demand in the market for government debt: the scarcity premium does not move. In a final step, I aggregate changes in the scarcity premiums of the four largest euro-area countries to create a single series of asset purchase news.

With this identified series at hand, I estimate the effects of asset purchases on financial markets in event-study regressions. Central bank purchases of government debt reduce not only the yields of euro-area government bonds, but also the yields of corporate bonds and non-euro area government and corporate bonds. At the same time, stock prices rise in the euro area and in other advanced economies. In addition, asset purchases reduce expected risk-free interest rates in line with a signaling effect and strongly depreciate the euro against all major currencies. I further study whether the financial effects of asset purchases differ across euro-area countries. First, I find that asset purchases reduce sovereign yields rather homogeneously. Even though point estimates are slightly larger for Spain and Italy, sovereign yield spreads vis-à-vis Germany do not fall significantly. This finding stands in contrast to some of the related literature. For example, Altavilla et al. (2015) find sovereign spreads to fall on days with news about the Public Sector Purchase Programme (PSPP) between September 2014 and March 2015. A potential explanation for these contrasting findings are the different samples. Compared to previous studies, my analysis uses a later and much longer sample (October 2014 - January 2020) during which sovereign risk premiums were relatively low on average. Therefore, there was little scope for asset purchases to have heterogeneous effects by reducing risk premiums in countries with concerns about sovereign solvency. Second, I find that asset purchases have heterogeneous effects on stock prices. National stock indices increase the most in Germany (DAX), France (CAC 40), and the Netherlands (AEX). The common characteristic is that these stock indices include a number of very large firms. The evidence thus suggests that asset purchases may benefit large firms more than small firms. This heterogeneous effect on national stock indices alongside the homogeneous effect on sovereign bond yields may raise doubts about the prevalent view that asset purchases mostly benefit highly indebted countries.

Institutional Background. The analysis focuses on asset purchases under the ECB's PSPP. Choosing the euro area as a setting strengthens the identification strategy that I propose, for two reasons. First, the identification strategy builds on bond scarcity, which allegedly was more severe in Europe than elsewhere, as Coeuré (2018) explains. Second, I can exploit that the same monetary policy applies to a number of countries.

I focus on the PSPP because it is by far the largest of the ECB's asset purchase programs put in place before the COVID-19 crisis. The left panel of Figure 1 illustrates quarterly holdings under the four asset purchase programs, which comprise the ECB's Asset Purchase Programme (APP). By December 2019, the ECB held around €2100bn worth of euro-area government and agency debt under the PSPP, which amounts to roughly 20% of euro-area annual Gross Domestic Product (GDP). In comparison, the other programs were relatively small. The ECB held assets worth around €264bn under the Covered Bond Purchase Programme (CBPP), €184bn under the Corporate Sector Purchase Programme (CSPP), and €28bn under the Asset-Backed Securities Purchase Programme (ABSPP).

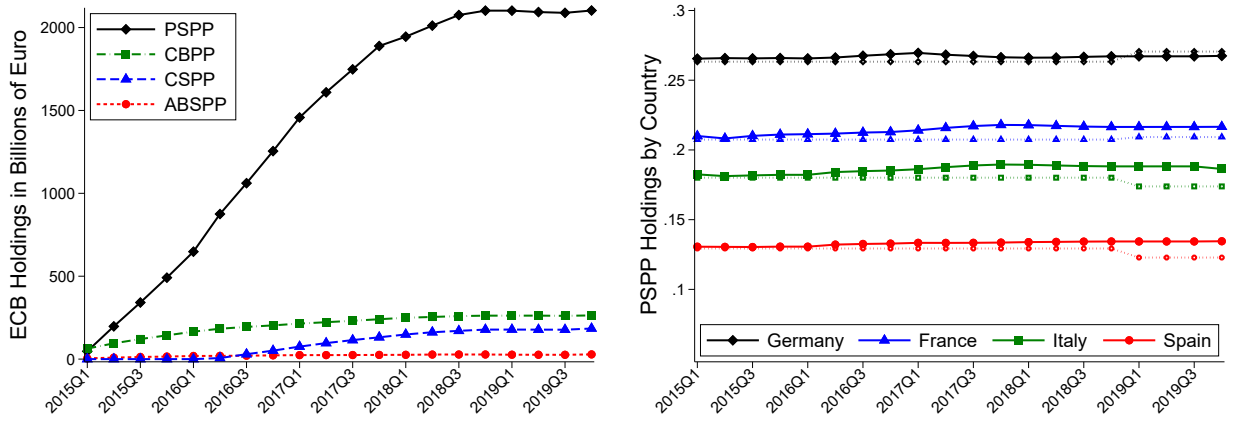


Figure 1: The European Central Bank's Asset Purchase Programme

Notes: The left panel shows ECB holdings under the Public Sector Purchase Programme (PSPP), the Covered Bond Purchase Programme (CBPP), the Corporate Sector Purchase Programme (CSPP), and the Asset-Backed Securities Purchase Programme (ABSPP) by quarter in billions of euro. In the right panel, solid lines depict ECB holdings under the Public Sector Purchase Programme (PSPP) by country as a share of total PSPP holdings (excluding supranationals), by quarter. Dashed lines depict the share according to the ECB's capital key. Source: ECB.

Throughout, the distribution of PSPP purchases across eligible countries was guided by the ECB's capital key. Therefore, the distribution was known in advance. The right

panel of Figure 1 shows that country shares of holdings under the PSPP fluctuated little over time and that these shares closely align with the respective shares according to the ECB's capital key.[2] In contrast, both the duration of the program and monthly purchase amounts were adjusted several times.[3] Therefore, the future amount of ECB purchases was uncertain. Hence, any ECB communication possibly changed expectations about the future amount of ECB purchases, but not about its distribution across countries.

Related Literature. This paper relates to three strands of the literature. First and foremost, it relates to the literature identifying monetary policy shocks from high-frequency monetary surprises. A seminal contribution is Gürkaynak et al. (2005a), who show that more than one factor is required to explain U.S. high-frequency monetary surprises. Brand et al. (2010) apply their methodology to the euro area. A number of recent papers, including Nakamura and Steinsson (2018), Zhang (2019), Kerssenfischer (2019), Cieslak and Schrimpf (2019), and Jarociński and Karadi (2020), emphasize that non-monetary news, such as the dissemination of central bank information, are an important aspect of central bank communication. In a similar spirit, Kroencke et al. (2021) identify changes in how investors evaluate and price risks during FOMC meetings. Andrade and Ferroni (2021) identify Delphic and Odyssean forward guidance shocks in the euro area. Swanson (2021) separates conventional monetary policy, forward guidance and asset purchase shocks for the U.S. by means of a factor rotation. Lewis (2019) identifies asset purchase shocks for the U.S. alongside other monetary policy shocks based on intraday time-varying volatility.

In the literature focusing on euro-area monetary policy shocks, two highly influential and closely related papers are Jarociński and Karadi (2020) and Altavilla et al. (2019). Jarociński and Karadi (2020) decompose interest rate surprises into policy and information shocks and show that these two shocks have very different macroeconomic effects. However, they do not further decompose policy shocks into shocks due to particular policy measures. Altavilla et al. (2019) decompose interest rate surprises into target, timing, forward guidance,

[2] A new capital key entered into force on January 1, 2019, causing small changes in the prescribed country shares. To not disrupt market conditions, the ECB decided to adjust its portfolio allocation very gradually. Therefore, an increase in the total amount of purchases would still imply an increase in the amount purchased from each country.

[3] A detailed timeline of major events can be found in Hammermann et al. (2019).

and QE shocks using the factor rotation methodology of Swanson (2021) and the split of the ECB communication into a press release and a press conference. They document differences in the financial effects of the different policy measures and make another significant contribution by publishing and maintaining the Euro Area Monetary Policy Event-Study Database (EA-MPD), which I utilize. A limitation is that their methodology does not separate policy from information shocks. The contribution of this paper is to fill the gap between these two papers and provide a measure of news about asset purchases, which is not subject to either of the limitations mentioned above. In contrast to the policy shock of Jarociński and Karadi (2020), the measure of news about asset purchases that I develop is separated from news about other policy measures. In contrast to the QE factor of Altavilla et al. (2019), the measure does not correlate with information shocks.

Second, I add to the literature on the heterogeneous effects of asset purchases across regions. Wieladek and Pascual (2016), Burriel and Galesi (2018), and Hachula et al. (2020) provide VAR-based assessments of heterogeneous real effects across countries of the ECB's unconventional monetary policies. Altavilla et al. (2015), Altavilla et al. (2019), and De Santis (2020) examine the heterogeneous effects of the PSPP on euro-area sovereign bond yields. Georgiadis and Gräb (2016) and Bubeck et al. (2018) evaluate the financial spillover effects of the PSPP beyond the euro area. To the best of my knowledge, my paper is the first to document heterogeneous effects of the PSPP on euro-area national stock indices.

Third, I relate to the much broader literature studying the financial market impact of large-scale asset purchases. Krishnamurthy and Vissing-Jorgensen (2011) provide an early assessment of the channels of the Federal Reserve's QE programs. Droste et al. (2021) draw conclusions about the impact of asset purchases using evidence from Treasury auctions. D'Amico and King (2013) distinguish between stock and flow effects of asset purchases.[4] Krishnamurthy et al. (2018) consider the effects of the ECB's Securities Markets Programme (SMP) and Outright Monetary Transactions (OMT). Koijen et al. (2021), Bergant et al. (2018) and Albertazzi et al. (2021) analyze portfolio flows before and during the PSPP

[4]By construction, asset purchase news only measure stock effects of asset purchases, i.e. the effect of the ECB holding (or announcing to hold) a certain stock of assets. Potential flow effects of asset purchases, i.e. the effect of the actual purchases of these assets, are not measured. D'Amico and King (2013) find stock effects to be quantitatively more important. See Schlepper et al. (2018) for an analysis of the flow effects of purchases under the PSPP in the market for German sovereign bonds.

period using quarterly transaction-level data.

The remainder of this paper is structured as follows. Section 2 explains the identification of asset purchase news, presents the resulting series and compares the identification strategy to existing methodologies. Section 3 estimates the effects of asset purchases on financial markets and interprets the findings. Section 4 performs a number of robustness checks and section 5 concludes.

2 Identification Strategy

A large literature strives to identify exogenous variation, so called shocks, in monetary policy in order to study its causal effects and mechanisms. This is an intricate task for several reasons. First, monetary policy decisions are taken in view of current and future economic conditions, making them endogenous to the state of the economy. Second, economic agents form expectations about future monetary policy decisions, such that many decisions are anticipated. A popular strategy to deal with both issues and identify plausibly exogenous variation in monetary policy is high-frequency identification. The idea is to measure monetary policy shocks using the change in monetary policy expectations in a narrow window around official policy communication events.[5]

High-frequency identification requires a high-frequency measure which reflects monetary policy expectations. For expectations about unconventional monetary policy, long-term interest rates, such as government bond yields, are commonly used in the literature.[6] However, long-term interest rates reflect expectations of multiple policy measures. Since several policy decisions are typically announced jointly, the change in long-term interest rates in an event window reflects potentially a combination of a conventional monetary policy shock, a forward guidance shock, and news about asset purchases[7]. To deal with this multidimension-

[5]Since not the policy decision itself, but the change in policy expectations is measured, the shock is unexpected. Moreover, since initial monetary policy expectations take into account the state of the economy and there are by assumption no other news during during the narrow window, the shock is not endogenous to economic conditions. See Ramey (2016) for a more detailed discussion.

[6]For example, Andrade et al. (2016) use the German 5-year sovereign yield, Hachula et al. (2020) use a number of euro-area 2-year sovereign yields excluding Germany, and Gambetti and Musso (2020) use a GDP-weighted euro-area 10-year yield. Altavilla et al. (2019) and Andrade and Ferroni (2021) use interest rate swap rates of various maturities.

[7]Throughout, I refer to this shock as news about asset purchases, or, *asset purchase news*. Other papers

ality of central bank communication, Altavilla et al. (2019) use a factor rotation methodology to identify target, timing, forward guidance, and QE shocks from high-frequency changes in interest rates of various maturities.

While the method used by Altavilla et al. (2019) has greatly enhanced our understanding of monetary policy, it also relies on the strong assumption that all interest rate movements in event windows reflect news about monetary policy. However, Jarociński and Karadi (2020) among others find that interest rate movements in event windows reflect not only policy decisions, but also the revelation of information about the state of the economy, so called central bank information shocks. Therefore, this paper proposes an alternative way to measure news about asset purchases, which does not rely on ruling out information shocks.

While the objective is similar, the approach in this paper differs from the two aforementioned papers. In particular, to measure monetary policy expectations, I do not use high-frequency changes in risk-free interest rates, precisely because these reflect multiple monetary policy and also information shocks. Instead, I construct a component of government bond yields, labeled the "scarcity premium", which around central bank communication arguably reflects only a single monetary policy shock, namely, news about asset purchases. The fundamental idea is that asset purchases, as opposed to other monetary policy or information shocks, reduce the effective supply of government debt and thereby affect the scarcity premium. I explain the measurement of the scarcity premium and the construction of asset purchase news in detail in subsection 2.1. I confirm that the resulting series reflects news about asset purchases in subsection 2.2, and demonstrate that it is indeed unrelated to other monetary policy and information shocks in subsection 2.3. In subsection 2.4, I compare the identification strategy to the approach of Altavilla et al. (2019).

2.1 Measuring Asset Purchase News

The basic idea of my identification strategy is to not use high-frequency changes in the entire government bond yield, but to decompose the yield and isolate a component, which around

use the terms *asset purchase shocks*, *QE shocks*, or *LSAP shocks* to refer to the same or a very similarly defined shock.

ECB communication reflects only news about asset purchases. I draw on Krishnamurthy et al. (2018)[8] and consider the following decomposition of the nominal yield of a sovereign bond of country c with remaining term to maturity T at time t:

$$
\begin{aligned}
yield_t^{c,T} = & \underbrace{i_t^T}_{\substack{Overnight\ Index\ Swap\ (OIS)\ rate\ with\ maturity\ T}} \\
& + \underbrace{CountryRiskPremium_t^{c,T}}_{\substack{Credit\ Default\ Swap\ (CDS)\ rate\ of\ country\ c\ with\ maturity\ T}} \\
& + \underbrace{ScarcityPremium_t^{c,T}}_{Component\ of\ interest}
\end{aligned}
$$

The first component, i^T, is the risk-free nominal interest rate associated with the remaining maturity. It is straightforward to measure this component from maturity-matched interest rate swaps using the Euro OverNight Index Average (EONIA) as the underlying floating rate.[9] The second component, the country-specific risk premium, compensates the investor for bearing the risk of and loss in case of sovereign default and currency redenomination. For the time period of interest, it is straightforward to measure this premium from maturity-matched credit default swap (CDS) rates traded under the 2014 ISDA Credit Derivatives Protocol.[10] CDS contracts based on the 2014 ISDA Credit Derivatives Protocol, which are traded since September 22, 2014, insure against sovereign default and currency redenomination. CDS contracts under the previous 2003 ISDA Credit Derivatives Protocol

[8]Krishnamurthy et al. (2018) use a similar decomposition to understand sovereign yield changes in response to specific ECB policy communication events, associated with news about the Securities Markets Programme (SMP), the Outright Monetary Transactions (OMT), and the Long-Term Refinancing Operations (LTROs). I draw on their decomposition, but reverse the logic. Instead of assuming the type of news and assessing the effect on yield components, I assume that one particular yield component reflects only one type of news and thereby back out a quantitative measure of this type of news.

[9]These interest rate swap contracts are used to hedge interest rate exposure. The buyer periodically pays a fixed rate (the swap rate) to the seller and receives the current (floating) rate in return, thereby trading interest rate risk. Without uncertainty, the swap rate would equal the average expected interest rate. With uncertainty, the swap rate will also include a risk premium which compensates the seller for bearing the interest rate risk. Therefore, the overnight index swap (OIS) rate using the Euro OverNight Index Average (EONIA) as the underlying floating rate is a convenient measure of the Euro risk-free interest rate along with the interest rate risk premium. Lloyd (2021) explains that counterparty risk in OIS contracts is minor. EONIA OIS contracts are fairly liquid and available for a wide range of maturities ranging from two weeks to thirty years.

[10]Available maturities range from six months to thirty years. I use CDS contracts denominated in euro.

do not insure against currency redenomination for G-7 countries.[11] Therefore, I restrict my sample to the period after the introduction of the 2014 CDS protocol to be able to account for redenomination risk.

The third component, which I label the scarcity premium[12], is measured residually. This premium should be negligible under no-arbitrage considerations (Duffie, 1999). However, in the data it is non-negligible and negative due to the particularities of sovereign bonds.[13] On the one hand, sovereign bonds are commonly used to collateralize transactions, serve as a safe storage facility, and count as high-quality liquid assets towards banks' *liquidity coverage ratio*.[14] Therefore, holding them provides utility to banks and financial institutions. This gives rise to a rather inelastic, or, in the words Krishnamurthy and Vissing-Jorgensen (2011), *unique* demand for sovereign bonds. On the other hand, the supply of sovereign bonds by euro-area governments is limited and rather inelastic due to constraints imposed by the European Union's fiscal rules. First and foremost, the Stability and Growth Pact limits government deficits and debt. The combination of this unique demand for and limited supply of sovereign debt gives rise to the scarcity premium.[15] Since this component is computed as a residual, the measured scarcity premium will also reflect any additional drivers of the sovereign yield, which are not captured by the other two components.[16]

I propose to use the change in this scarcity premium around ECB policy communication as a measure of asset purchase news. Thereby, I make two key assumptions, which are visualized in figure 2. First, I assume that news about asset purchases affect the scarcity premium (Relevance Assumption). The supply of sovereign debt by governments and the

[11] Three countries, for which I compute this decomposition, are G-7 countries, namely Germany, France, and Italy.

[12] I refer to this component as a premium, because, while it *decreases* the yield, it *increases* the price of the bond. This nomenclature follows the definition of the liquidity premium in Nagel (2016).

[13] Over the sample period used in this paper (10/2014 - 01/2020), the scarcity premium is on average negative for all four countries (Germany, France, Italy, Spain), for which the decomposition is done. It is largest (in absolute terms) for Germany with on average 40 basis points.

[14] Under the Basel III regulatory framework, banks are required to have a liquidity coverage ratio (LCR) of 100% or higher. The LCR is defined as high-quality liquid assets divided by total net liquidity outflows over 30 days. Sovereign bonds count as high-quality liquid assets without haircut.

[15] I choose this nomenclature to emphasize that the premium is a result of particularities on the demand and the supply side. Closely related concepts which solely emphasize particularities on the demand side are the *safety premium* (Krishnamurthy and Vissing-Jorgensen, 2011), the *convenience yield* (Krishnamurthy and Vissing-Jorgensen, 2012) or the *utility premium*.

[16] As discussed in the following paragraph, this is not an issue as long as such additional drivers are not affected by central bank communication besides news about asset purchases.

demand by investors being rather inelastic, this must be the case, because asset purchases reduce the effective supply of sovereign bonds available to the public. Since actual purchases do not take place until well after their announcement, however, this requires that financial markets are sufficiently forward-looking. Second, I assume that other elements of central bank communication, including conventional monetary policy shocks, forward guidance shocks and central bank information shocks, do not affect the scarcity premium (Exogeneity Assumption). The rationale is that these shocks affect sovereign yields only via the risk-free interest rate and the country-specific risk premium. None of these shocks affects the scarcity premium, because they do not affect demand and supply for sovereign bonds in a relevant magnitude. I provide empirical support for this assumption in subsection 2.3. Nevertheless, two concerns remain. First, the ECB could affect the scarcity premium directly by announcing major changes to its collateral framework. I confirm that no major changes were announced on Governing Council Meeting days in the sample.[17] Second, ECB communication could potentially induce safe haven flows by changing investors' perception of risk. Fontana and Scheicher (2016) discuss in the context of the euro crisis that a flight to safety may have shifted bond demand from peripheral to core euro-area countries. To address this concern, I extract the common component of changes in the scarcity premium of several countries to not capture shifts in bond demand between euro-area countries. I explain this final step in the following.

In principle, the decomposition explained above can be applied to sovereign bonds of any maturity and any euro-area country, whose bonds were bought under the PSPP. I focus on 10-year sovereign yields, because bond scarcity is a bigger issue among long-term bonds.[18] Moreover, these bonds did not trade below the Deposit Facility Rate (DFR) before December 2016, which would have made them ineligible for ECB purchases at that point in time. This is particularly relevant for Germany and France, whose short-term government bonds did periodically trade below the DFR. Furthermore, I focus on euro-area countries

[17]There are two potentially interfering regulatory changes. On December 8, 2016, the Eurosystem introduced cash collateral for PSPP securities lending facilities. On December 14, 2017, there were changes to collateral eligibility criteria for unsecured bank bonds. However, neither of these regulatory changes seems quantitatively important.

[18]For example, over the sample period used in this paper (10/2014 - 01/2020), the average scarcity premium for German 5-year bonds (-32 basis points) is smaller in absolute terms than the average premium for 10-year bonds (-40 basis points).

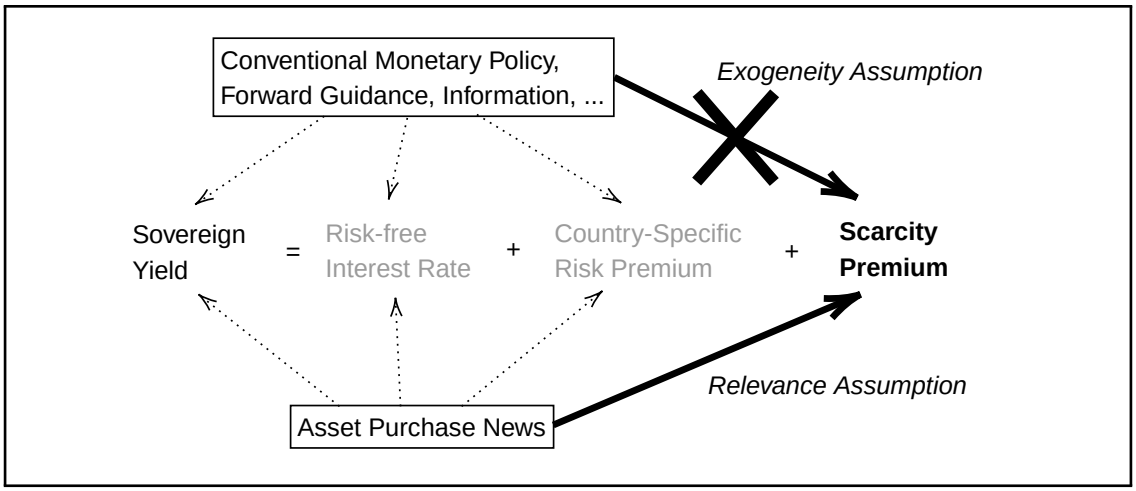


Figure 2: Visualization of Identifying Assumptions

with a large and highly liquid market for government debt, which is necessary to compute yield changes in a narrow window around policy communication. I select Germany (DE), France (FR), Italy (IT), and Spain (ES).

I obtain changes in 10-year sovereign yields and 10-year OIS rates in a narrow window around ECB communication on Governing Council Meeting days from the Euro Area Monetary Policy Event Study Database (EA-MPD) made available by Altavilla et al. (2019). I use the full *monetary event window* to capture news about asset purchases from the press conference and the press release.[19] To the best of my knowledge, intraday data on CDS rates is not available. Therefore, I use daily changes in 10-year CDS rates from Thomson Reuters Eikon.[20]

In order to create a single measure of asset purchase news and minimize the influence of country-specific noise, I aggregate information from all four countries. Therefore, I extract

[19]The monetary event window (13:30 CET - 15:45 CET) brackets both, the press release published at 13:45 Central European Time (CET), and the press conference starting at 14:30 CET and lasting for around an hour. Before March 2016, the ECB communicated news about its unconventional policies in the press conference only. Since then, some information about unconventional policies is already included the press release. Thus, to capture all news about asset purchases, it is necessary to use the full monetary event window.

[20]The lack of data on intraday CDS rate changes makes it necessary to trade off noise in the scarcity premium outside the monetary event window against changes in the CDS rate outside the window. Since in the relevant time period, CDS rates were relatively low and there was little concern about debt sustainability, I opt for this mixed-frequency approach. In a previous draft, I opted for daily data throughout and found broadly similar results. There are three missing observations in the series of German CDS rate changes which are set to 0.

the first principal component of the changes in the scarcity premiums around ECB policy communication on Governing Council Meeting days. Beforehand, the country-specific series are standardized to unit variance to avoid mechanically giving higher weights to more volatile series. This approach resembles Gürkaynak et al. (2005a) and Nakamura and Steinsson (2018), who condense information from interest rates of various maturities using principal component analysis. I discuss the aggregation of individual series in more detail in Appendix D and show that the final series is not driven by any single country.

2.2 Series of Asset Purchase News

The principal component decomposition identifies the series of asset purchase news only up to sign and scale. I define the sign such that positive asset purchase news[21] reduce scarcity premiums and therefore constitute expansionary realizations. Moreover, I follow Altavilla et al. (2019) and normalize the scale such that asset purchase news reduce the 10-year OIS rate by one basis point. Figure 3 shows the resulting series of asset purchase news. The sample contains a total of 44 ECB Governing Council Meeting days between October 2014 and January 2020.

The realizations of asset purchase news align well with the interpretation in the financial press of the respective ECB communication. The first large expansionary realization occurs on January 22, 2015, the day on which the PSPP was officially announced. Although market participants were expecting the ECB to introduce a large-scale asset purchase program, they did not anticipate its size.[22] The largest contractionary realization is December 3, 2015. On this day, the ECB decided to extend its asset purchases for only 6 months, while markets had expected a longer extension or even an increase in the monthly amount of purchases.[23] This event was preceded by a large expansionary realization on October 22, 2015, when President Draghi surprisingly hinted at an expansion of asset purchases at the

[21] In the nomenclature of the literature, asset purchase news could also be called asset purchase news *shocks*. I remain by *asset purchase news* for the sake of brevity. In addition, I frequently omit the supplement *expansionary* when referring to (positive) asset purchase news.

[22] The *Financial Times* wrote "Mario Draghi's bond-buying plan outstripped expectations". (Financial Times, January 22, 2015, "Mario Draghi's bond-buying plan outstrips expectations" by Claire Jones)

[23] *The Guardian* wrote "Mario Draghi dashes expectations that the European Central Bank would pump more new money into the eurozone economy each month". (The Guardian, December 3, 2015, "ECB Day: markets tumble as Draghi disappoints investors - as it happened" by Graeme Wearden)

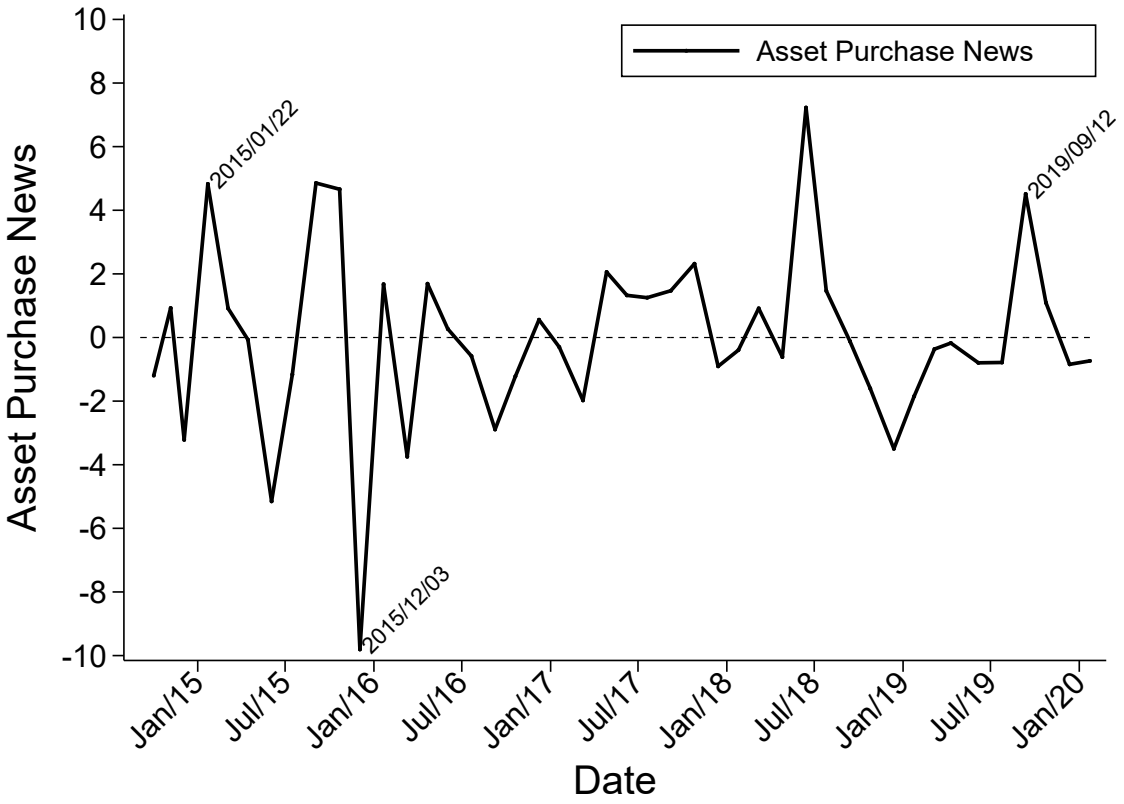


Figure 3: Series of Asset Purchase News

Notes: Observations refer to ECB Governing Council Meetings. Positive (negative) realizations denote expansionary (contractionary) asset purchase news. Sample: October 2014 - January 2020.

next Governing Council Meeting.[24] The last large realization is September 12, 2019, the day on which the ECB announced to restart net asset purchases. This decision was only partly expected and therefore amounted to expansionary news.[25]

2.3 The Exogeneity Assumption

Figure 3 and the discussion in subsection 2.2 confirm that the series of asset purchase news captures key announcements regarding the PSPP, thereby supporting the relevance assumption. In this subsection, I provide empirical support for the exogeneity assumption which

[24] *The Guardian* wrote "Mario Draghi, the president of the European Central Bank, has stunned markets by signalling that he is prepared to cut interest rates and step up quantitative easing to stave off the risk of a renewed economic slump in the eurozone". (The Guardian, October 22, 2015, "Mario Draghi: ECB prepared to cut interest rates and expand QE" by Heather Stewart)

[25] *Market Watch* wrote "Economists had been less certain whether the ECB would also move to relaunch its quantitative easing program at its September meeting, but policy makers did so." (Market Watch, September 12, 2019, 'ECB cuts key rate, relaunches QE to shore up eurozone economy")

states that the scarcity premium is not systematically affected by other elements of central bank communication, including conventional monetary policy shocks, forward guidance shocks, and central bank information shocks.

To confirm that the series of asset purchase news does not correlate with information shocks, I compute central bank information and monetary policy shocks using a rotational sign restriction approach in the spirit of Jarociński and Karadi (2020) and as implemented in Jarociński (2021). The idea is that interest rate changes accompanied by stock price changes of the opposite sign reflect monetary policy shocks. Interest rate changes accompanied by stock price changes of the same sign reflect information shocks. With multiple underlying monetary policy shocks, the measured monetary policy shock will reflect a combination of these. However, the information shock is still the only underlying shock, which induces a positive co-movement of interest rates and stocks. Therefore, it can still be identified. As explained in Jarociński (2021), sign restrictions only provide set identification and there are three options to uniquely identify the series of information shocks. I report results using all three series. More details of the construction of information and policy shocks are explained in Appendix A. Table 1 shows that the correlation of asset purchase news and information shocks is very small and insignificant, regardless of the series of information shocks. This is important because I investigate the effect of asset purchases on stock prices in the following section. The presence of information shocks would bias the estimates towards zero. Moreover, the correlation of asset purchase news with the policy shock is large and significant. This is as expected and reflects that asset purchases were the most important policy tool during this time period.

To support the assumption that the scarcity premium is not affected by other monetary policy shocks, I turn to the period before the PSPP. Before 2014, there were asset purchase news for Italy and Spain, since their government bonds were purchased under the Securities Markets Programme (2010-2012), but there weren't any asset purchase news for Germany and France. Thus, the series of scarcity premium changes for Germany and France should only pick up noise and under the exogeneity assumption be uncorrelated with monetary policy shocks.[26] As an out-of-sample test, I therefore compute the correlation of changes

[26]To compute the scarcity premiums before October 2014, I need to use CDS rates from contracts traded

	Information Shock			Policy Shock		
	Baseline	Median	Poor Man's	Baseline	Median	Poor Man's
Asset Purchase News	-0.07	-0.11	-0.07	0.74***	0.74***	0.75***
	(0.6546)	(0.4863)	(0.6533)	(0.0000)	(0.0000)	(0.0000)

Table 1: Correlation of Asset Purchase News with Policy and Information Shocks

Notes: Table reports correlation coefficients, while p-values are in parentheses. Signs of all shocks are normalized to decrease interest rates. Policy and information shocks are identified from 1Y, 2Y, 5Y, and 10Y OIS rate surprises in the monetary event window. "Baseline" shocks use the rotation which matches the variance shares of poor man's shocks as in Jarociński (2021). "Median" shocks use the median rotation among all admissible rotations. "Poor Man's" shocks are computed as in Jarociński and Karadi (2020). The sample is 10/2014 - 01/2020 (N=44). See Appendix A for more details on the construction of the shocks.

in these two scarcity premiums with a number of identified monetary policy shocks between July 2011 to December 2013.[27] I use the policy shocks identified in Jarociński and Karadi (2020) and Kerssenfischer (2019) using the co-movement of interest rates and stock prices. Moreover, I use the target and Delphic and Odyssean forward guidance shocks identified in Andrade and Ferroni (2021) using the co-movement of 1-year OIS and 5-year inflation-linked swap (ILS) rates.[28] Finally, I use the press release surprise in short-term OIS rates, which is a common measure of conventional monetary policy surprises. Table 2 displays the correlation coefficients of these identified monetary shocks with the German and French scarcity premium changes. All correlations are small and not significantly different from zero, thereby lending support to the exogeneity assumption.

2.4 A Comparison to Altavilla et al. (2019)

The paper most closely related to mine is Altavilla et al. (2019), who also develop a measure of news about asset purchases contained in ECB communication. They exploit that the ECB communication on Governing Council Meeting days is split into two parts. At 13:45 Central European Time (CET), a press release is published. At 14:30 CET, a press conference begins,

under the 2003 protocol, which do not insure against currency redenomination. Therefore, the scarcity premiums potentially include a redenomination risk premium, which could respond to monetary policy actions. Bayer et al. (2018) discuss redenomination risk in the euro area between January 2010 and October 2014 and argue that it was sizable even for Germany and France.

[27]Before July 2011, high-frequency data on OIS rates is unavailable, as discussed in Altavilla et al. (2019). Throughout 2014, there was already discussion about large-scale asset purchases in the euro area, meaning that there may have been asset purchase news.

[28]I thank Filippo Ferroni for sharing the series of Delphic and Odyssean forward guidance shocks.

	Δ Scarcity Premium Germany	**Δ Scarcity Premium France**
Jarocinski & Karadi (2020)		
→ Policy Shocks	0.04 *(.8362)*	0.07 *(.7293)*
Kerssenfischer (2019)		
→ Policy Shocks	-0.03 *(.8747)*	-0.01 *(.9768)*
Andrade & Ferroni (2019)		
→ Delphic Forward Guidance Shocks	0.00 *(.9996)*	0.07 *(.6973)*
→ Odyssean Forward Guidance Shocks	-0.01 *(.9614)*	0.14 *(.4500)*
→ Target Shocks	0.25 *(.1763)*	0.27 *(.1463)*
Press Release Surprises		
→ 1-M OIS Rate	0.04 *(.8235)*	0.10 *(.6015)*
→ 3-M OIS Rate	0.10 *(.6050)*	0.14 *(.4505)*
→ 1-Y OIS Rate	0.00 *(.9978)*	0.08 *(.6689)*

Table 2: Correlation of Monetary Policy Shocks with DE & FR Scarcity Premium Changes

Notes: Sample includes all ECB GCMs from July 2011 to December 2013 (N=30). p-values are reported in parentheses.

which lasts around one hour. For identifying the effects of unconventional monetary policy measures, including asset purchases, they use a narrow window around the press conference only. Altavilla et al. (2019) extract factors from changes in interest rates (1-month to 10-years) in this narrow window and rotate them using the methodology of Swanson (2021). Thus, they extract three factors and rotate them to make the factors interpretable as a timing, a forward guidance (FG), and a QE factor.[29] The QE factor provides a measure of news about asset purchases, similar in interpretation to the measure developed in this paper. Figure A.8 provides a visual comparison of the two measures.

There are several appealing features of the methodology employed by Altavilla et al. (2019). Most importantly, their approach aims to identify *all* shocks which move interest rates around ECB communication events. Moreover, they look at a very long sample, starting in January 2002. This paper takes a much narrower approach and aims to identify merely a single shock and for a shorter period of time, starting in October 2014. Moreover, publishing and maintaining the Euro Area Monetary Policy Event-Study Database (EA-MPD)

[29]The identifying assumptions are (i) that forward guidance and QE do not load onto the 1-month OIS rate surprise, and (ii) that the QE factor has a minimal variance before August 2008. By definition, the three factors are required to be orthogonal.

by Altavilla et al. (2019) constitutes a significant contribution in itself.

There are two potential drawbacks of the state-of-the-art methodology, as applied by Altavilla et al. (2019) among others. This paper improves on these. First and foremost, the identification strategy does not consider that interest rate movements around central bank communication reflect not only policy decisions, but also the revelation of information about the state of the economy. Jarociński and Karadi (2020) show that it is essential to distinguish between these central bank information shocks and true monetary policy shocks. Indeed, also Altavilla et al. (2019) explain in their section 5 that the presence of information shocks may explain the surprisingly small and insignificant estimates of the effect of some policy factors on stock markets.[30] I formalize this point in Table 3, which shows that the QE factor identified in Altavilla et al. (2019) appears to correlate significantly with the series of information shocks identified in the spirit of Jarociński and Karadi (2020). This table uses exactly the same series of information and policy shocks, that were used in table 1.[31] The FG factor identified in Altavilla et al. (2019) also correlates significantly with the series of information shocks. Moreover, both factors correlate with the policy shocks, as expected. Thus, table 3 shows that the QE and FG factors not only reflect monetary policy, but also the revelation of information about the state of the economy. As I have shown in table 1, my proposed measure does not correlate with information shocks. The identification strategy proposed in this paper circumvents the issue that movements in risk-free interest rates also reflect the revelation of information by not directly using movements in risk-free interest rates to identify asset purchase news.

A seemingly straightforward approach to get rid of information shocks in the factor rotation methodology works as follows. One could simply orthogonalize the three factors with respect to the identified information shock. This would work under the assumption that the decomposition of interest rate surprises into three policy factors in the first place is not affected by the presence of information shocks.[32] This, however, may be problematic in

[30] "Therefore, the presence of these two types of policy [monetary policy; information revelation] can make the response of the stock market, on average, insignificant and can produce the results reported in Table 7." (ABGMR, p.174)

[31] The construction of these shocks is explained in Appendix A.

[32] That is, each factor picks up only the policy measure it is supposed to pick up plus the information shock. E.g. $QEFactor_t = \epsilon_t^{QE} + \gamma_1 \epsilon_t^{Info}$, $FGFactor_t = \epsilon_t^{FG} + \gamma_2 \epsilon_t^{Info}$, etc.

	Information Shock			Policy Shock		
	Baseline	Median	Poor Man's	Baseline	Median	Poor Man's
QE Factor	0.39***	0.36***	0.37***	0.58***	0.60***	0.59***
	(0.0038)	(0.0078)	(0.0057)	(0.0000)	(0.0000)	(0.0000)
FG Factor	0.28**	0.27*	0.33**	0.23*	0.24*	0.2
	(0.0447)	(0.0550)	(0.0167)	(0.0987)	(0.0799)	(0.1436)

Table 3: Correlation of QE and FG Factors with Policy and Information Shocks

Notes: Table reports correlation coefficients, while p-values are in parentheses. Signs of all shocks are normalized to decrease interest rates. Policy and information shocks are identified from 1Y, 2Y, 5Y, and 10Y OIS rate surprises in the monetary event window. "Baseline" shocks use the rotation which matches the variance shares of poor man's shocks as in Jarociński (2021). "Median" shocks use the median rotation among all admissible rotations. "Poor Man's" shocks are computed as in Jarociński and Karadi (2020). The sample is 01/2014 - 01/2020 (N=53). See Appendix A for more details on the construction of the shocks.

light of the evidence above that the information shock correlates with two of the estimated factors (QE, FG). The information shock therefore induces a correlation among the factors. Yet, factors must be uncorrelated by definition. Therefore, the decomposition of interest rate surprises into three factors in the presence of information shocks must be different from the decomposition without concurrent information shocks.

Another approach to get rid of information shocks in the factor rotation methodology would be to combine the approaches of Jarociński and Karadi (2020) and Altavilla et al. (2019). One could simply augment the data matrix used in Altavilla et al. (2019) with the stock market surprise and rotate the factors using a combination of the restrictions of both papers. Using this augmented data matrix, one would expect to find 3 factors (timing, forward guidance, information) in the pre-QE sample (01/2002 - 01/2014, as in Altavilla et al. (2019)) and one additional factor (QE) in the full sample (01/2002 - 01/2020). Surprisingly, using the Cragg and Donald (1997) test, I find three factors in both samples.[33] Finding the same amount of factors in both samples is at odds with the prior that a new factor (QE) emerged after 2014. It also impedes using the identifying assumption, to separate QE and FG, that one factor (QE) was only active in the later part of the sample and should therefore have a minimal variance beforehand. For sure there are ways to identify a QE factor which

[33]The Cragg and Donald (1997) test is a bottom-up test, which tests the hypothesis of k factors against the alternative hypothesis of there being more than k factors. In the pre-QE sample, the hypothesis of two factors can be rejected ($p = 0.0420$), while the hypothesis of three factors cannot ($p = 0.4009$). Similarly, in the full sample, the hypothesis of two factors can be rejected ($p = 0.0054$), while the hypothesis of three factors cannot be rejected ($p = 0.4917$).

is unrelated to the revelation of information in a factor rotation framework. However, this exploration shows that doing so is not straightforward and might require different variables, a different sample, and different identifying assumptions. While this approach certainly constitutes an interesting avenue for future research, I pursue an entirely different strategy in this paper. Instead of choosing surprises of variables which are affected by many shocks and seeking to disentangle them, I construct a variable, the scarcity premium, which arguably reflects only a single shock.

There is another concern with the way the existing literature proceeds. Namely, it identifies the QE factor from the press conference window only. This is fine before March 2016, because then, the press release only contained information about the ECB's interest rate decisions. Thus, for measuring news about asset purchases, it was sufficient to look at the press conference window. Since March 2016, however, the press release also includes key decisions regarding the ECB's asset purchase programs. Therefore, to measure all news about asset purchases, one needs to look at both, the press release window and the press conference window, as this paper does when measuring asset purchase news. A limitation, however, of the identification strategy developed in this paper is that it cannot exploit the split of the communication into two windows. This is because changes in CDS rates are only available at a daily frequency. Therefore, it is not possible to investigate whether measured asset purchase news stem from information released with the press release or during the press conference.

3 Results

With the series of asset purchase news at hand, I explore the effects of central bank purchases of government debt on financial markets. Particular attention is paid to heterogeneous effects across euro-area countries, as well as spillover effects beyond the market for euro-area sovereign debt.

To estimate the effects of asset purchase news, I use the following regression specification commonly used in the event-study literature:

$$y_t = \alpha + \beta s_t + \epsilon_t \tag{1}$$

where y_t is the one-day change in some financial variable of interest, s_t is the series of asset purchase news, and ϵ_t is the error term. The parameter of interest is β, which captures the effect of asset purchase news on the dependent variable. Throughout, I use standard errors robust to heteroskedasticity and autocorrelation.[34] Any noise remaining in the measure of asset purchase news introduces an attenuation bias, distorting the estimate $\hat{\beta}$ towards zero. In that case, $\hat{\beta}$ provides a lower bound on the true effect of asset purchases. I focus on the impact effects of asset purchase news and document their persistence over the following days in Appendix B.

3.1 Risk-Free Interest Rates

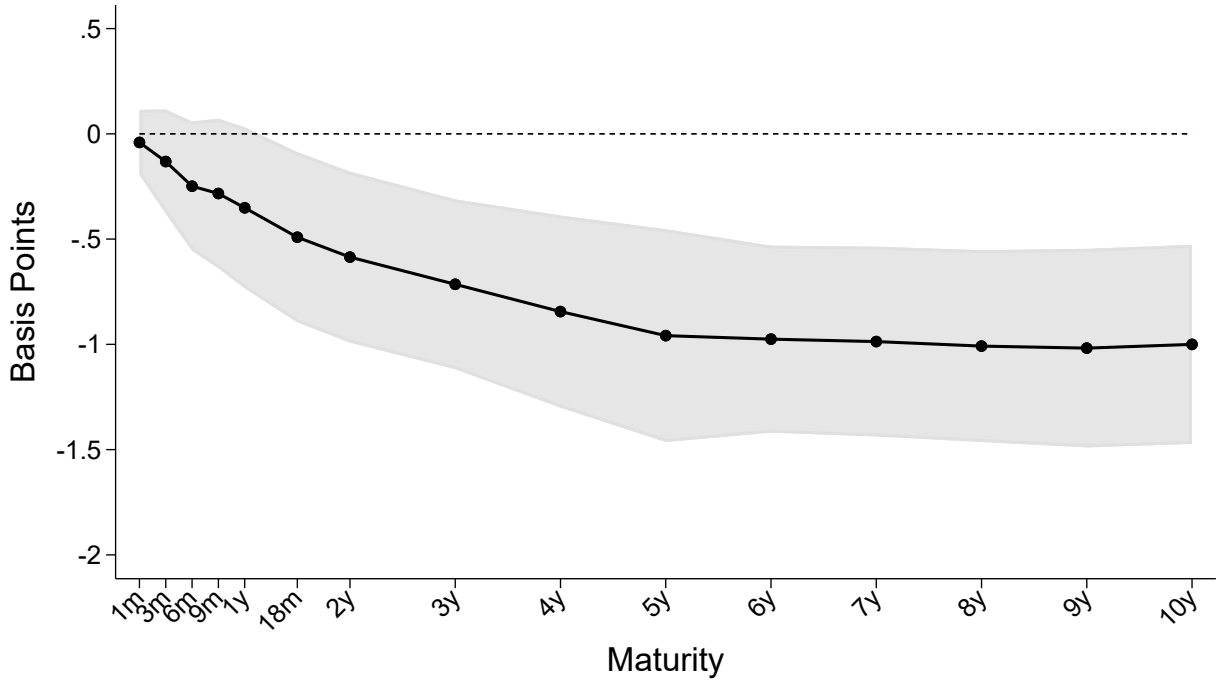
To understand how asset purchases affect financial markets, it is crucial to know how these affect risk-free interest rates. Usually, and also in the case of the PSPP, large-scale asset purchase programs are employed to provide additional monetary stimulus to an economy at or near the ELB. Therefore, short-term risk-free interest rates cannot be reduced much more. Nevertheless, asset purchases can still reduce long-term risk-free interest rates by reducing expected future short-term interest rates. This is referred to as the signaling channel of asset purchases.[35] On the one hand, asset purchases can be seen as a commitment to keep rates low, because the central bank would make losses on its purchased assets if it raised interest rates. On the other hand, asset purchases may signal that the central bank is willing to maintain an accommodative policy stance in the future.

Figure 4 illustrates the impact effect of asset purchase news on risk-free nominal interest rates of various maturities (upper panel) and implied forward rates at various horizons (lower panel). As in section 2, I use interest rate swaps to measure risk-free interest rates and implied forward rates.[36] Asset purchases do significantly reduce long-term interest rates

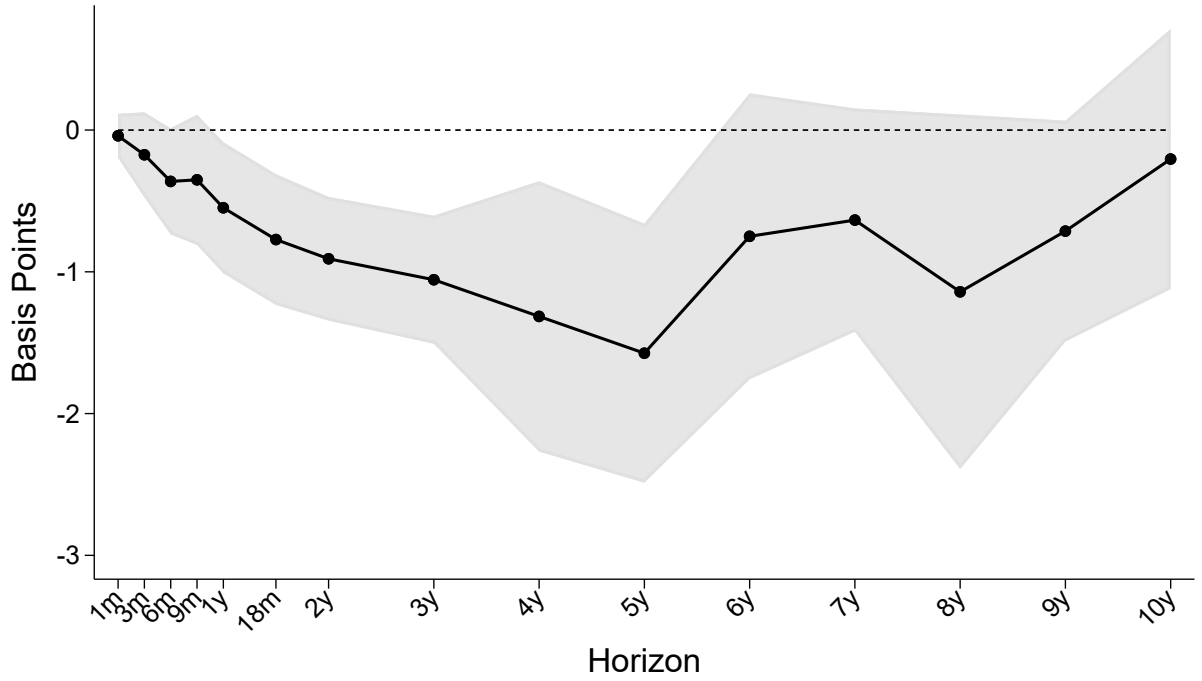
[34]Since the regressor, i.e. the asset purchase news, is generated, standard errors should reflect the additional uncertainty arising from its construction. However, confidence intervals constructed using a wild bootstrap in the spirit of Swanson (2021) are barely distinguishable from those constructed with asymptotic standard errors robust to heteroskedasticity and autocorrelation. Therefore, I remain with asymptotic standard errors. Gürkaynak et al. (2005a) similarly observe that bootstrapping standard errors leads to almost identical results.

[35]Bauer and Rudebusch (2014) discuss the importance of the signaling channel for the Fed's QE programs and argue that it contributed 40-50% to the decline of long-term Treasury yields.

[36]As explained in footnote 9, interest rate swap rates include an interest rate risk premium. Therefore, the results in Figure 4 may not only reflect falling interest rate expectations, but also reduced interest rate



(a) OIS Rates



(b) OIS-implied Forward Rates

Figure 4: Response of Risk-Free Interest Rates to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Shaded areas depict the 90% confidence interval using robust standard errors.

risk.

as can be seen from the upper panel. Recall that the magnitude of the effect on the 10-year OIS rate is normalized to one basis point as in Altavilla et al. (2019). The lower panel provides strong support for the signaling channel, as asset purchase news reduce implied forward rates, while the effect is largest and most significant between 1- and 5-years ahead. The peak effect at the 5-year horizon is later than observed for conventional monetary policy and forward guidance shocks.[37]

3.2 Bond Markets

It is largely undisputed that the ECB was successful in reducing sovereign yields in the euro area with the PSPP. In this subsection, I investigate the drivers of this effect, heterogeneous effects across euro-area countries, and spillover effects to corporate and non-euro-area bond markets.

3.2.1 Euro-Area Sovereign Bonds

To understand how news about asset purchases affect euro-area sovereign bond markets, I reuse the bond yield decomposition introduced in section 2 for the identification of asset purchase news. Thus, I consider sovereign yields to be the sum of the risk-free interest rate, a risk premium, and a scarcity premium. The previous subsection presented evidence that news about asset purchases reduce risk-free interest rates. Thus, yields should fall accordingly. Moreover, asset purchases may influence bond yields through the risk premium by affecting solvency considerations. Finally, asset purchase news must affect the scarcity premium in sovereign yields, since they are identified via changes in this scarcity premium.

Figure 5 confirms that asset purchase news reduce sovereign yields across maturities, using the example of German bonds.[38] The effect is significant at the 10% significance level for maturities of two years and longer. As can be seen from the same figure, the magnitude of the effect exceeds the effect on risk-free interest rates at longer horizons, implying that

[37]For example, Brand et al. (2010) estimate a downward-sloping maturity response pattern to ECB policy decisions. Altavilla et al. (2019) estimate a very similar downward-sloping response pattern to their target factor. Moreover, the effects of forward guidance in Andrade and Ferroni (2021) and Altavilla et al. (2019) peak earlier than 5-years ahead.

[38]I use German bonds here, because these are often considered risk-free. The effects on French, Italian, and Spanish sovereign yields are displayed in Figure A.5.

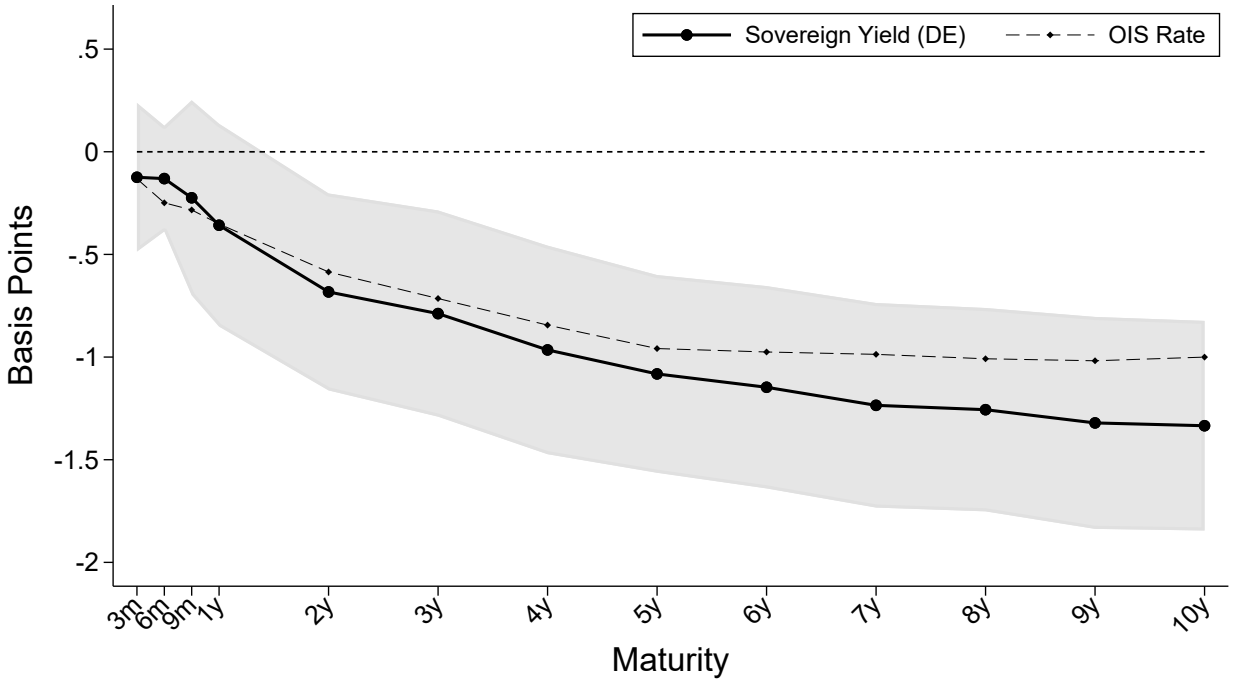


Figure 5: Response of German Sovereign Yields to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Shaded areas depict the 90% confidence interval using standard errors robust to heteroskedasticity.

either the risk premium or the scarcity premium, or both, were affected as well. This comes as no surprise, since I use changes in scarcity premiums to identify asset purchase news. A concern might therefore be that the measured statistical relationship is to some extent mechanical, because I use the German 10-year yield as a dependent variable and also for the construction of asset purchase news. The robustness exercise in subsection 4.1 shows, however, that estimates barely change if Germany is left out of the construction of the series of asset purchase news.

A recurring question with respect to asset purchases in the euro area is whether some countries are affected more than others. A common narrative is that sovereign yields fall most in countries with initially high sovereign yields. On the one hand, this could be due to asset purchases reducing risk premia and particularly so in countries with initially high risk premia. On the other hand, this could be due to a portfolio rebalancing towards riskier bonds in search for yield. Altavilla et al. (2015) find evidence for the former mechanism using a number of events in late 2014 and early 2015.

Figure 6 shows the effect on 10-year sovereign yields of the ten largest euro-area countries. While I do find the effects to be strongest on Spanish and Italian yields, the point estimates are very similar across countries. Figure A.6 confirms that sovereign spreads vis-à-vis Germany do not fall significantly. Figure 6 also decomposes the effect on 10-year yields into the effect on the three yield components. This reveals that country-specific risk premia (light gray bars) react very little and fall only for Portugal. Thus, I find little evidence for the "credit risk channel" of asset purchases, which holds that asset purchases reduce bond yields by reducing sovereign risk premia. The slight heterogeneity in responses across countries is mostly driven by the scarcity premium (medium gray bars). This heterogeneity is consistent with a portfolio rebalancing in search for yield, but could also reflect other reasons. The robustness exercise in subsection 4.1 shows that the lack of heterogeneity is unchanged if the country on the left hand side of the regression is left out of the construction of the series of asset purchase news. Another interesting observation from figure 6, which is in line with the evidence in Altavilla et al. (2019), is that the fall in the risk-free rate explains the majority of the reduction in sovereign yields.

In sum, the evidence shows that asset purchases reduce sovereign yields across countries and maturities. In contrast to some of the related literature, I do not find the effects to be very heterogeneous across countries. For example, Altavilla et al. (2015) find asset purchases to narrow euro-area sovereign spreads. These contrasting findings can potentially be explained by the different samples. Altavilla et al. (2015) use a number of events between September 2014 and March 2015. The current paper uses a later and much longer sample (October 2014 - January 2020), during which sovereign risk premia were on average lower.[39] Thus, there was less scope for asset purchases to have heterogeneous effects by reducing sovereign risk premia. Figure A.7 shows that using the QE factor of Altavilla et al. (2019) in the sample used throughout this paper, one finds similarly homogeneous effects across countries. This corroborates that the finding of no heterogeneous effects is a feature of the sample period and not of the series of shocks. I conclude that the effect of asset purchases on sovereign yields differs across countries only under certain circumstances, such as elevated

[39]Credit default swap rates under the 2003 protocol, which measure the default risk premium, were on average 148 (Italy) and 106 (Spain) basis points over the period September 2014 - March 2015. The averages fall to 130 (Italy) and 79 (Spain) basis points over the period October 2014 - January 2020.

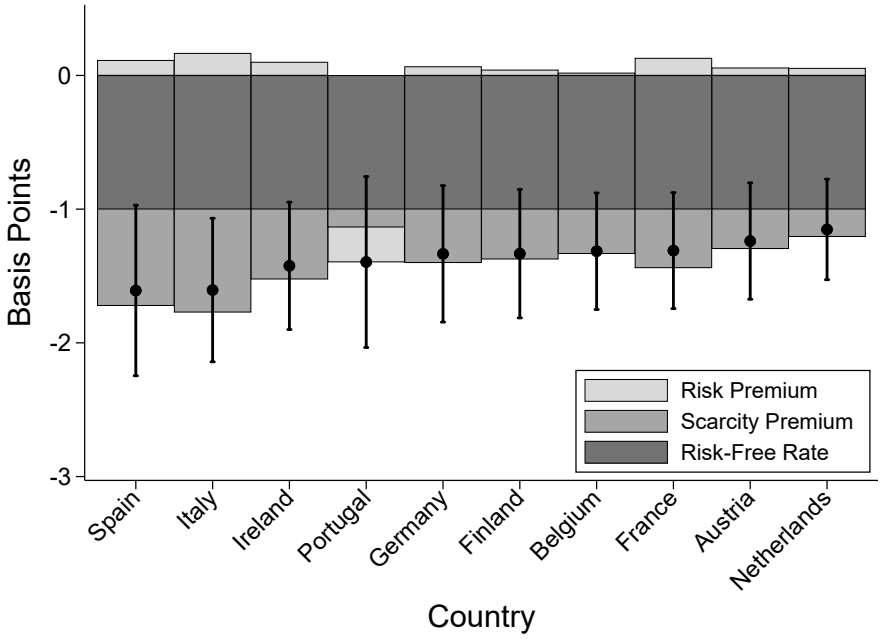


Figure 6: Response of 10-Year Sovereign Yields to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity. Dark gray bars depict the effect on risk-free interest rates, medium gray bars the effect on scarcity premiums, and light gray bars the effect on country-risk premiums.

sovereign risk premia.

3.2.2 Corporate Bonds

In light of the previous results, one would expect there to be spillover effects of asset purchase news to the market for corporate bonds. On the one hand, the fall in risk-free interest rates should reduce corporate yields. On the other hand, risk premia might fall or there might be a portfolio rebalancing towards corporate bonds. Importantly, there is no direct effect on the corporate bond market, as under the PSPP, the ECB only purchased government and supranational bonds. I do not measure asset purchase news with respect to the Corporate Sector Purchase Programme (CSPP), under which the ECB directly purchased corporate bonds.[40] This section focuses on the effect of asset purchase news on a number of euro-area

[40]In section 4.2, I discuss the CSPP in more detail and verify that it does not drive the results regarding the corporate sector.

corporate bond indices.[41] Due to a lack of country-specific corporate bond indices, I do not study heterogeneities across euro-area countries in the effect of asset purchase news on corporate yields. Nonetheless, this constitutes a highly interesting avenue for future research.

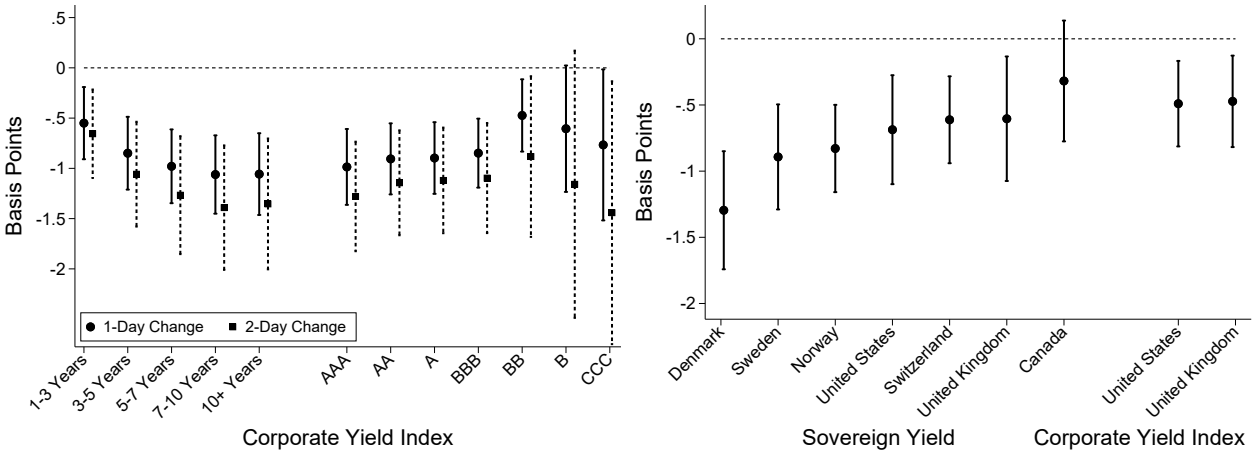
Figure 7a displays the effect of asset purchase news on euro-area corporate bond yield indices of various maturities and credit ratings. Evidently, asset purchases reduce corporate yields across the board. In line with the effect on risk-free interest rates and sovereign yields, the effect increases with the remaining maturity. However, speculative grade corporate bond yields fall less strongly than investment grade yields in regressions using the 1-day yield change. This suggests that the market for speculative grade corporate debt is relatively illiquid, which hampers the transmission of lower interest rates. Indeed, using 2-day changes, the effect is more homogeneous across rating buckets. Moreover, using 2-day yield changes, the effect of asset purchase news is larger on corporate yield indices in general, which is suggestive of illiquidities in all segments of the market for corporate debt. Recalling that the effect of asset purchase news on 10-year risk-free interest rates is normalized to 1 basis point, we find corporate spreads over the risk-free rate to fall only when using 2-day changes.[42] Thus, there seems to be an effect on corporate bond yields beyond the risk-free rate reduction, so via risk premia or a portfolio rebalancing.

3.2.3 Non-Euro Area Bonds

Figure 7b shows that asset purchases by the ECB not only affect euro-area sovereign and corporate bond markets, but also bond markets beyond the euro area. 10-year sovereign yields of several advanced economies with tight financial linkages to the euro area (Denmark, Sweden, Norway, United States, Switzerland, United Kingdom) fall significantly in response to asset purchase news. Canadian sovereign yields also fall but insignificantly. Corporate yields in the U.S. and U.K. also fall significantly. On the one hand, these effects could be driven by reduced risk-free interest rates also in these other economies. On the other hand,

[41] I use the Bank of America Merrill Lynch EMU Corporates Non-Financial AAA, AA, A, and BBB indices, the Merrill Lynch Euro High Yield BB, B, and CCC and Lower indices, as well as the Bank of America Merrill Lynch EMU Corporates Non-Financial 1-3Yr, 3-5Yr, 5-7Yr, 7-10Yr, and 10+Yr indices.

[42] For example, the spread between the 7-10-year corporate yield index and the 10-year OIS rate falls by a mere 6 basis points ($t = -0.56$) in a 1-day regression, but by almost 36 basis points ($t = -1.76$) in a 2-day regression.



(a) Euro-Area Corporate Bond Yields (b) Non-Euro Area Bond Yields

Figure 7: Spillovers to Euro-Area Corporate and Non-Euro Area Bonds

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily (or 2-day) change, measured in basis points. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

they could reflect a portfolio rebalancing towards non-euro area bonds. The latter mechanism aligns well with Bergant et al. (2018), who find evidence for a portfolio rebalancing towards debt instruments issued in non-euro area advanced economies during the PSPP period using quarterly portfolio holdings data.

3.3 Exchange Rates

Before turning to stock markets, it is useful to estimate how asset purchase news affect exchange rates. Figures 6 and 7b have shown that euro-area sovereign bond yields fall to a larger extent than sovereign bond yields outside the euro area. According to the uncovered interest rate parity, this should go hand in hand with a depreciation of the euro. Indeed, Figure 8 shows that asset purchase news significantly depreciate the euro against all major currencies.

The magnitude of the depreciation is quite large, as a shock which reduces the 10-year OIS rate by one basis point depreciates the euro vis-à-vis the U.S. dollar by almost 0.25%. This magnitude exceeds most estimates of the effect of ECB conventional monetary policy on the exchange rate.[43] These findings echo Glick and Leduc (2018), who find that the

[43]For example, Altavilla et al. (2019) find their target factor, scaled to reduce the 1-month OIS rate by

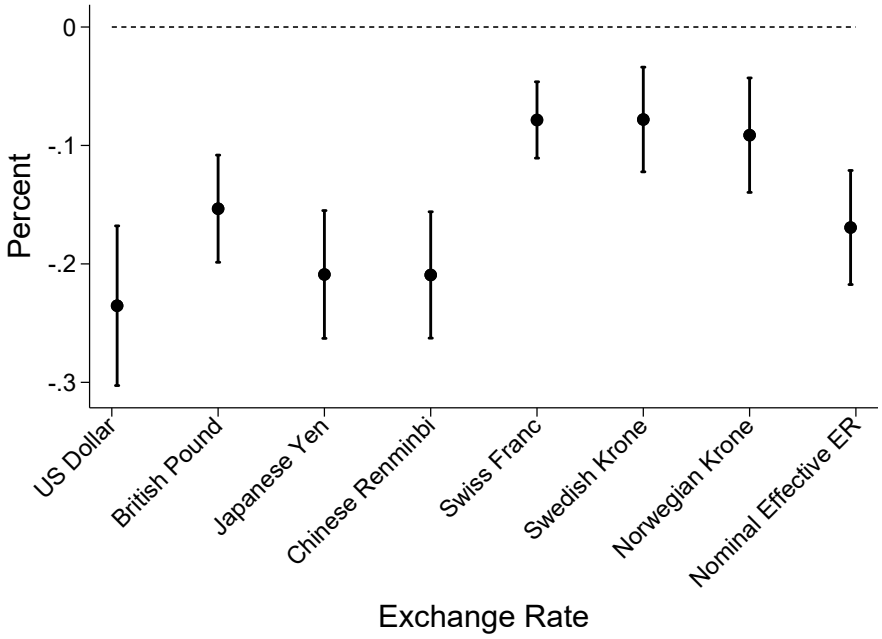


Figure 8: Response of the Euro Exchange Rates to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in percent. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity. Exchange rates are denoted in foreign currency per euro.

Fed's unconventional monetary policy announcements had a much larger effect on the dollar exchange rates than previous conventional monetary policy announcements.

3.4 Stock Markets

There are plenty of reasons to expect asset purchases to increase stock prices. First, the results in subsection 3.1 show that asset purchases reduce risk-free interest rates, which all else equal implies higher stock prices through a discounting effect. Moreover, asset purchases improve financing conditions for firms, as shown in subsection 3.2.2, which may increase stock prices via higher expected dividends. Finally, depreciated exchange rates, as shown in subsection 3.3, or generally higher growth expectations, may increase stock prices.

one basis point, to depreciate the euro by 0.06%.

3.4.1 Euro-Area Stocks

Figure 9 shows the effect of asset purchase news on euro-area national stock indices. As expected, stock prices rise significantly in the ten largest euro-area countries. The European STOXX 50 index similarly increases by almost 0.3% in response to asset purchase news, which reduce the 10-year OIS rate by one basis point. The QE factor of Altavilla et al. (2019) has a much smaller effect on the STOXX 50, in line with the conjecture that this measure of asset purchases also reflects central bank information shocks, which bias the estimate towards zero.

There is an interesting heterogeneity across euro-area countries in the magnitude of the effect of asset purchases on stock indices. Stock prices rise most in Germany (DAX), France (CAC 40), the Netherlands (AEX), and Italy (FTSE MIB). What these four countries have in common is that their national stock indices include a number of very large firms. By total market capitalization and market capitalization per constituent, the German, French and Dutch indices are a lot larger than the other indices. The Italian index is the ranks fifth. There are several mechanisms which could explain why asset purchases potentially benefit large firms more than small firms.[44] On the one hand, larger firms might have better bond market access and therefore be able to make better use of the improved financing conditions. On the other hand, larger firms might rely more on exports and therefore benefit more from the depreciated exchange rate. Moreover, large firms potentially benefit more from low interest rates in general, as in the model of Liu et al. (2019). Further investigating the reasons for this heterogeneity is high on my research agenda. I confirm that this finding is robust to using 2-day changes in stock prices (subsection 4.3), excluding key CSPP dates (subsection 4.2), and controlling for macroeconomic data releases (Appendix C).

3.4.2 Non-Euro Area Stocks

Figure 10 shows that asset purchases not only increase stock prices in the euro area, but also beyond it. Stock indices in a number of advanced economies with tight financial linkages to the euro area (Sweden, United Kingdom, Denmark, Switzerland, Norway, Canada, United

[44] Of course, none of the firms listed on these stock indices are "small" firms by usual definitions. Nevertheless, there are still large differences in size among these public firms.

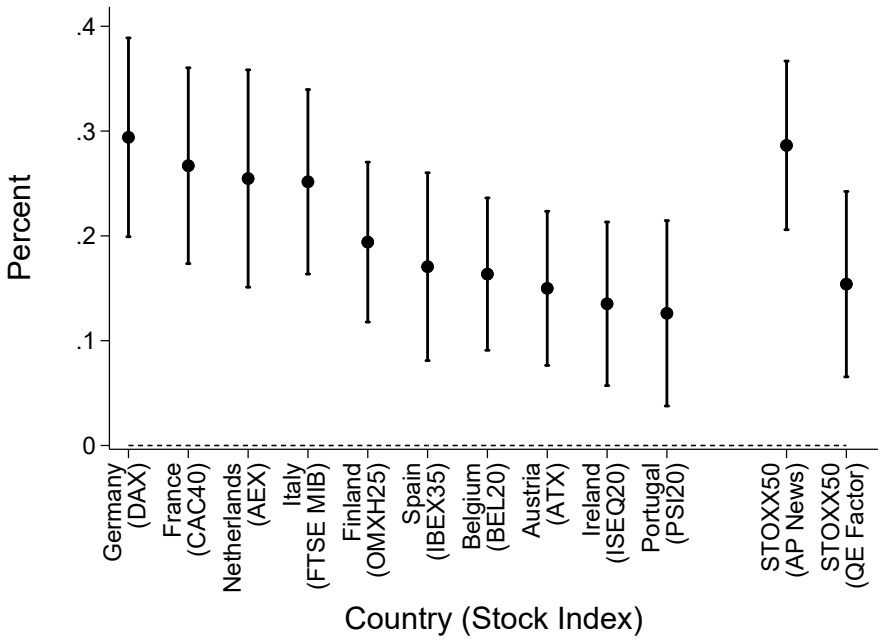


Figure 9: Response of National Stock Indices to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in percent. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

States) rise significantly. Again, there are several potential mechanisms for this, including lower discount rates and higher growth expectations. However, finding large effects on non-euro-area stock prices speaks against a central role of the exchange rate for the effect of asset purchase news on stock markets. Firms outside the euro area lose competitiveness due to the appreciation of their own currencies against the euro, but nevertheless see rising stock prices. In particular Norway, Sweden, and Switzerland should be hit hard by this, since a large share of their exports go to the euro area.

3.5 Comparison to the Literature

Since there already exists a substantial amount of research on the financial effects of the ECB's unconventional monetary policy measures, I compare the results found in this paper with those documented in the related literature. I focus on studies explicitly analyzing the effects of the PSPP. For an overview of the effects of the ECB's unconventional monetary policy measures more generally, see Fratzscher et al. (2016), Rogers et al. (2014), Dell'Ariccia et al. (2018) and references therein.

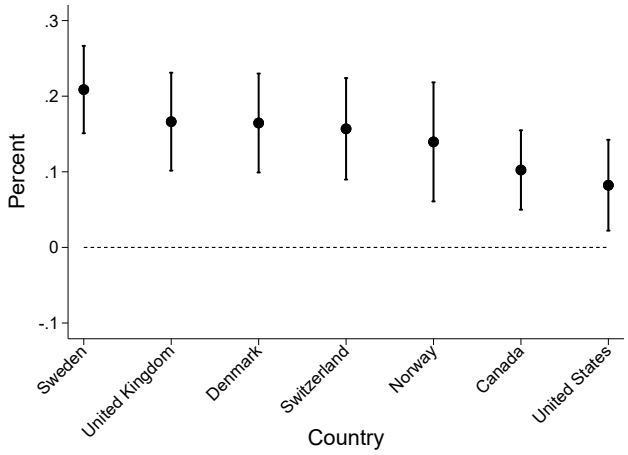


Figure 10: Response of Stock Indices Beyond the Euro Area

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in percent. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

I first of all document that the asset purchases under the PSPP reduce euro-area sovereign yields. This is a common finding and it is largely undisputed that the ECB was successful in reducing euro-area sovereign yields with the PSPP. A more interesting question is whether the fall in yields is heterogeneous across countries. I document yields to fall in a relatively homogeneous manner in response to asset purchase news. Thus, I do not find asset purchases to significantly narrow sovereign spreads. This is a surprising finding, since several papers, including Altavilla et al. (2015) and De Santis (2020) find asset purchases to narrow sovereign spreads. To reconcile these disparate findings, it is important to note that these papers focus on the first months of the PSPP and the period leading up to it, during which sovereign risk premia were still somewhat elevated.[45] I instead document the lack of significant heterogeneity in a later and much longer sample from October 2014 until January 2020. During this period of time, sovereign risk premia were on average lower, such that there was less scope for asset purchases to have heterogeneous effects by reducing sovereign risk premia. I show that using the shocks of Altavilla et al. (2019) in this longer sample, one finds a similar lack of heterogeneous effects. I conclude that the effect of asset purchases on sovereign yields differs across countries only under certain circumstances, such as elevated sovereign risk premia.

[45] Altavilla et al. (2015) consider events between September 2014 and March 2015. De Santis (2020) uses a sample from September 2014 to October 2015.

Second, I document spillover effects of asset purchases to euro-area corporate bond yields and stock prices. This is in line with Altavilla et al. (2015), who similarly find spillovers to corporate yields, which increase in size when 2-day yield changes are used, and euro-area stock prices. Georgiadis and Gräb (2016) and Bubeck et al. (2018) also document significant and sizeable effects of the PSPP on euro-area equities. As discussed before, Altavilla et al. (2019) find surprisingly small and insignificant effects of QE on stock prices, potentially due to the presence of information shocks. Moreover, I document that asset purchases increase national stock indices more strongly in countries with very large firms (Germany, France, Netherlands, Italy). To the best of my knowledge, this finding has not been documented previously. De Santis (2020) points out that stock prices rose most in Germany and Italy on average across three QE dates in 2015, but does not further analyze this observation.

Finally, I show that asset purchases reduce bond yields and increase stock prices in advanced economies beyond the euro area, and depreciate the euro. These three effects are also documented in Georgiadis and Gräb (2016) and Bubeck et al. (2018). A small difference is that Georgiadis and Gräb (2016) do not find yields in the U.S. to fall significantly, whereas Bubeck et al. (2018) and I do find them to fall significantly. The finding that asset purchases depreciate the euro is also documented in Altavilla et al. (2015), Altavilla et al. (2019), and Dedola et al. (2021).

4 Robustness Checks

I now discuss a number of robustness exercises. In the interest of space, I focus on figures 6 and 9 to show that the most interesting findings of heterogeneous effects on euro-area national stock indices and a lack thereof on sovereign bond yields are robust.

4.1 Leave-One-Out Asset Purchase News

I use some financial variables, such as 10-year sovereign yields, for the identification of asset purchase news and as outcome variables. Therefore, a concern might be that the measured statistical relationships between the series of asset purchase news and those variables is to some extent mechanical. To investigate this issue, I construct leave-one-out asset purchase

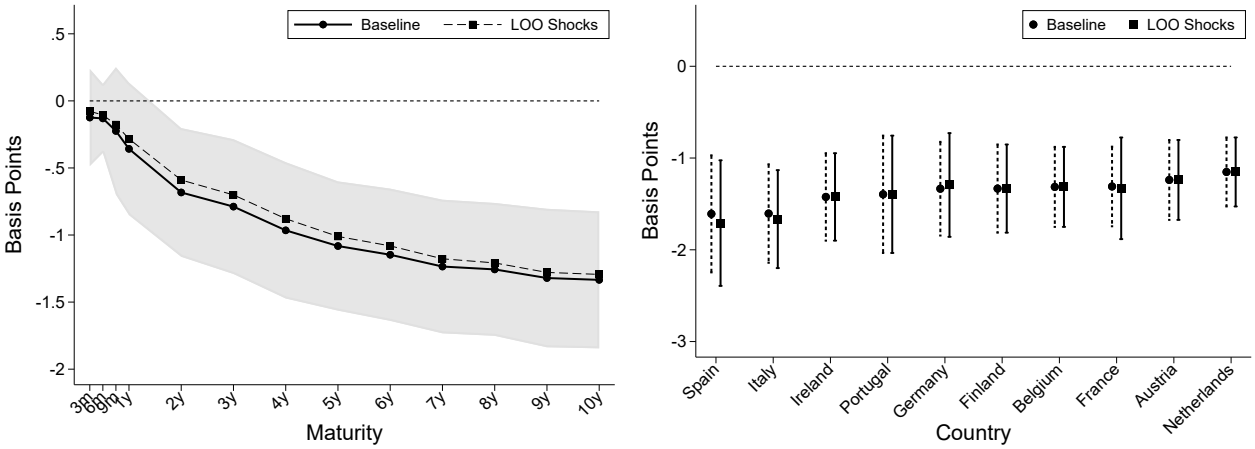
news series. These follow the identification strategy explained in section 2, but leave out one country in the aggregation of country-specific series of scarcity premium changes. Figure 11 replicates figures 5, 6 and 9 using the respective leave-one-out series for each country. As an example, panel (a) of figure 11 uses a series of asset purchase news constructed from French, Spanish, and Italian scarcity premium changes, because German yields are used as outcome variables. Evidently, estimates using leave-one-out shocks (squares) barely differ from the baseline estimates (circles). There are no meaningful differences in panels (b) and (c), either. This rules out the concern that the results regarding sovereign yields merely reflect a mechanical correlation. Note that the leave-one-out shock series for countries not used in the construction of baseline asset purchase news, such as Belgium, equal the baseline series.

4.2 Corporate Sector Purchase Programme

As discussed and demonstrated in section 2, the series of asset purchase news successfully captures key announcements regarding the PSPP and is unrelated to conventional monetary policy shocks, forward guidance shocks, and central bank information shocks. However, the series of asset purchase news might be correlated with news about *other* asset purchase programs, in particular the Corporate Sector Purchase Programme (CSPP), for two reasons. First, announcements of corporate bond purchases might have spillover effects to the sovereign bond market, therefore affecting the scarcity premium in sovereign bonds and, thereby, my measure of asset purchase news. Second, in the later part of my sample, the ECB oftentimes made announcements about total purchase amounts under the APP without specifying amounts under each single program. On the contrary, the left panel of figure 1 showed that the PSPP sizewise clearly dominates the other asset purchase programs. By December 2019, the ECB had spent more than 10 times as much under the PSPP as compared to the CSPP (€2100bn vs. €184bn). Relative to the amount of eligible bonds, the amount purchased under the PSPP also clearly exceeds the amount purchased under the CSPP.[46]

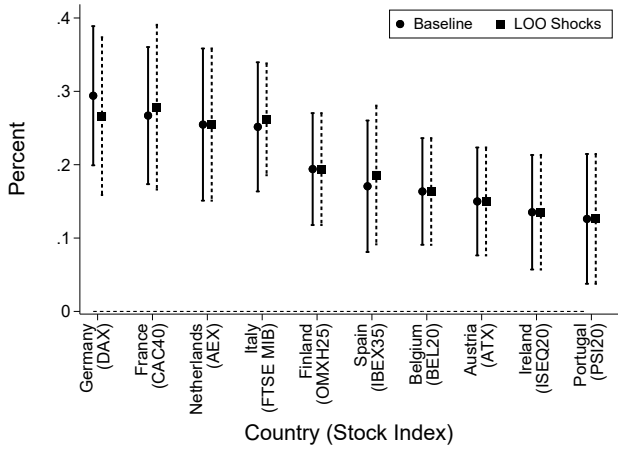
To verify empirically that my results regarding the corporate sector are not driven

[46]Relative to the respective eligible bond universe, the size of the PSPP exceeds the size of the CSPP almost by a factor of 2.



(a) Sovereign Yields (Germany)

(b) Sovereign Yields (Euro Area)

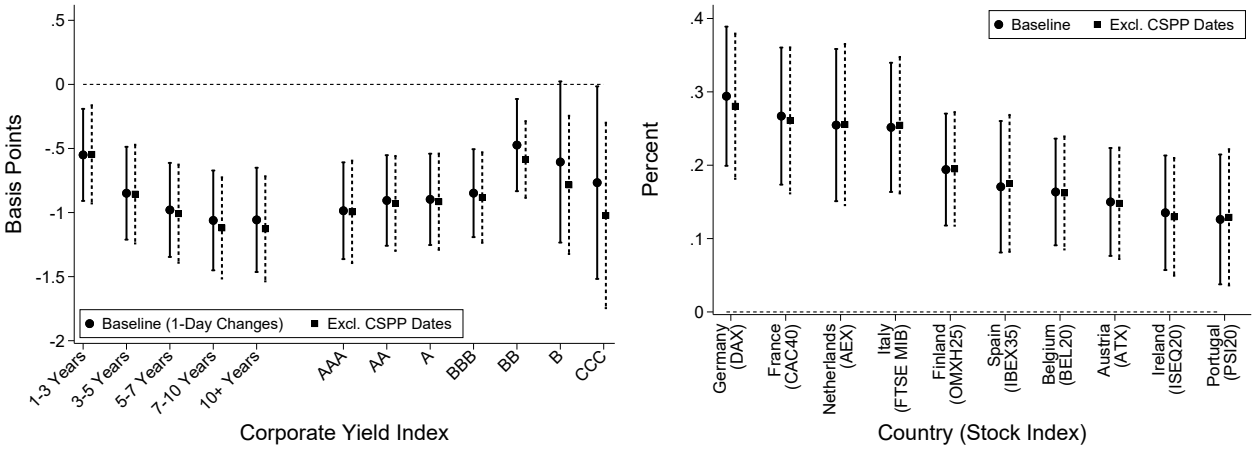


(c) National Stock Indices

Figure 11: Robustness Exercise - Leave-One-Out (LOO) Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points or percent (panel c). The squares represent the estimated $\hat{\beta}$ from separate regressions which use leave-one-out shocks. Shocks are scaled to reduce the 10-year OIS rate by 1 basis point. The shaded area / whiskers depicts the 90% confidence interval using standard errors robust to heteroskedasticity.

by the CSPP, I replicate figures 7a and 9 while leaving out major CSPP announcements. According to Dedola et al. (2021), such major announcements were made on March 10, April 21, and June 2 in 2016. Figure 12 shows that excluding these three dates leaves the effect of asset purchase news on corporate bonds and stock indices almost unchanged. I conclude that the results regarding the corporate sector are robust to excluding dates with major CSPP announcements.

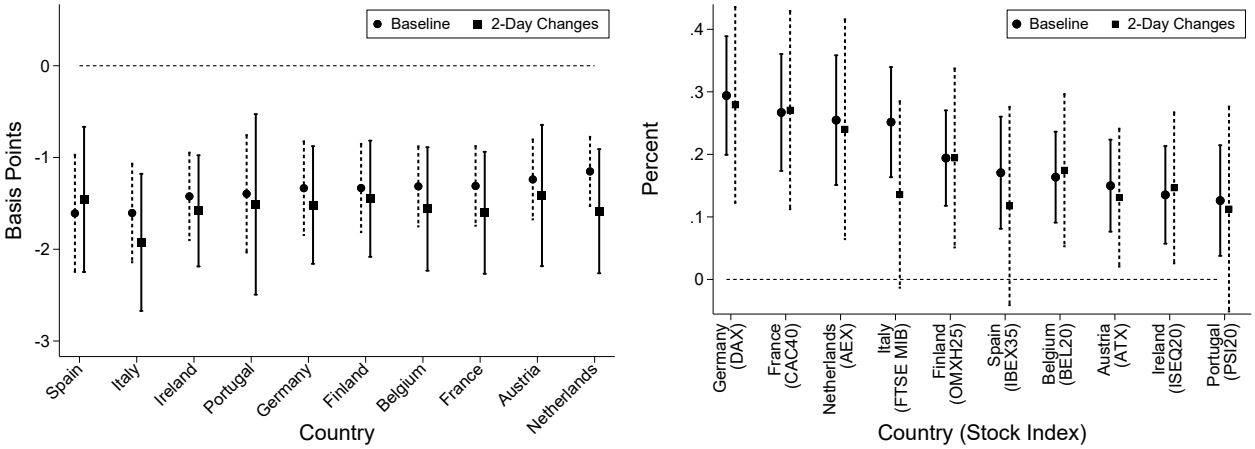


(a) Corporate Yields (b) National Stock Indices

Figure 12: Robustness Exercise - Corporate Sector Purchase Programme

Notes (left panel): The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. The squares represent the estimated $\hat{\beta}$ from separate regressions where the three CSPP dates have been excluded. Shocks are scaled to reduce the 10-year OIS rate by 1 basis point (before excluding dates). Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

4.3 2-Day Changes



(a) Sovereign Yields (Euro-Area) (b) National Stock Indices

Figure 13: Robustness Exercise - 2-Day Changes

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points (panel a) or percent (panel b). The squares represent the estimated $\hat{\beta}$ from separate regressions where y_t is the two-day change. Shocks are scaled to reduce the 10-year OIS rate by 1 basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

Subsection 3.2.2 showed that using 2-day changes in outcome variables makes a differ-

ence for the estimated effects of asset purchase news on corporate bond yields. To investigate whether this is also the case for other variables, figure 13 replicates figures 6 and 9 using 2-day changes in outcome variables. The left panel shows that the estimated effects on sovereign yields tend to be a bit larger. However, the lack of meaningful heterogeneity remains. Figure A.6 confirms that spreads do not change significantly using 2-day changes. The right panel shows that the estimated effects on national stock indices remain largely unchanged, except for Italy. The Italian stock index rises a lot less strongly using 2-day changes. Nevertheless, the main result that stock prices rise more strongly in Germany, France, and the Netherlands, the countries with particularly large firms, is unchanged.

5 Conclusion

In this paper, I propose a novel strategy to identify the effects of central bank purchases of government debt. I build on high-frequency identification and propose to use changes in the "scarcity premium", i.e. the component of government bond yields in excess of the risk-free interest rate and the risk premium, to measure news about asset purchases. The idea is that central bank asset purchases reduce the supply of government debt available to the public. The supply by governments and demand by investors being relatively inelastic, asset purchases thus reduce government bond yields, even in the absence of movements in risk-free interest rates or the risk premium. Hence, asset purchases affect the scarcity premium, in contrast to other monetary policy measures, which affect government bond yields only via the risk-free interest rate and the risk premium.

Employing the identified series, I estimate the effects of asset purchases on financial markets. I find that central bank purchases of government debt reduce not only the yields of euro-area government bonds, but also the yields of corporate bonds and non-euro area government and corporate bonds. At the same time, stock prices rise in the euro area and in other advanced economies. In addition, asset purchases reduce risk-free interest rates and strongly depreciate the euro against all major currencies. Investigating differences across euro-area countries, I find that asset purchases reduce sovereign bond yields rather homogeneously. That is, sovereign yield spreads vis-à-vis Germany do not fall significantly.

In contrast, I find that asset purchases have heterogeneous effects on stock prices. National stock indices increase the most in Germany (DAX), France (CAC 40), and the Netherlands (AEX), i.e. countries with relatively few concerns about sovereign solvency. These two pieces of evidence may raise doubts about the prevalent view that asset purchases mostly benefit highly indebted countries.

Directly investigating the real effects of asset purchases, for example by means of a structural VAR with an external instrument, is challenging due to data limitations, but constitutes an interesting avenue for future research. The identification strategy developed in this paper and the series of asset purchase news may provide a helpful starting point, in particular in contexts where concurrent information shocks are a concern.

References

Albertazzi, Ugo, Bo Becker, and Miguel Boucinha (2021). "Portfolio rebalancing and the transmission of large-scale asset purchase programs: Evidence from the Euro area". *Journal of Financial Intermediation 48*, 100896.

Altavilla, Carlo, Giacomo Carboni, and Roberto Motto (2015). "Asset purchase programmes and financial markets: lessons from the euro area". *ECB Working Paper No. 1864, European Central Bank*.

Altavilla, Carlo, Domenico Giannone, and Michele Lenza (2016). "The Financial and Macroeconomic Effects of the OMT Announcements". *International Journal of Central Banking 12* (3), 29–57.

Altavilla, Carlo, Luca Brugnolini, Refet Gürkaynak, Roberto Motto, and Giuseppe Ragusa (2019). "Measuring euro area monetary policy". *Journal of Monetary Economics 108*, 162–179.

Andrade, Philippe and Filippo Ferroni (2021). "Delphic and Odyssean monetary policy shocks: Evidence from the euro area". *Journal of Monetary Economics 117*, 816–832.

Andrade, Philippe, Johannes Breckenfelder, Fiorella De Fiore, Peter Karadi, and Oreste Tristani (2016). "The Reanchoring Channel of QE - The ECB's Asset Purchase Programme

and Long-Term Inflation Expectations". *ECB Working Paper No. 1956, European Central Bank*.

Bauer, Michael and Glenn Rudebusch (2014). "The signaling channel for Federal Reserve bond purchases". *International Journal of Central Banking 10* (3), 233–289.

Bayer, Christian, Chi Kim, and Alexander Kriwoluzky (2018). "The Term Structure of Redenomination Risk". *DIW Discussion Paper No. 1740, Deutsches Institut für Wirtschaftsforschung*.

Bergant, Katharina, Michael Fidora, and Martin Schmitz (2018). "International capital flows at the security level-evidence from the ECB's asset purchase programme". *ECMI Working Paper No. 7 October 2018, European Capital Markets Institute*.

Brand, Claus, Daniel Buncic, and Jarkko Turunen (2010). "The impact of ECB monetary policy decisons and communication on the yield curve". *Journal of the European Economic Association 8* (6), 1266–1298.

Bubeck, Johannes, Maurizio Michael Habib, and Simone Manganelli (2018). "The portfolio of euro area fund investors and ECB monetary policy announcements". *Journal of International Money and Finance 89*, 103–126.

Burriel, Pablo and Alessandro Galesi (2018). "Uncovering the heterogeneous effects of ECB unconventional monetary policies across euro area countries". *European Economic Review 101*, 210–229.

Cieslak, Anna and Andreas Schrimpf (2019). "Non-monetary news in central bank communication". *Journal of International Economics 118*, 293–315.

Coeuré, Benoit (2018). "The persistence and signalling power of central bank asset purchase programmes". *Speech at the 2018 US Monetary Policy Forum, New York City*.

Cragg, John and Stephen Donald (1997). "Inferring the rank of a matrix". *Journal of Econometrics 76* (1-2), 223–250.

D'Amico, Stefania and Thomas King (2013). "Flow and stock effects of large-scale treasury purchases: Evidence on the importance of local supply". *Journal of Financial Economics 108* (2), 425–448.

De Santis, Roberto (2020). "Impact of the asset purchase programme on euro area government bond yields using market news". *Economic Modelling 86*, 192–209.

Dedola, Luca, Georgios Georgiadis, Johannes Gräb, and Arnaud Mehl (2021). "Does a big bazooka matter? Quantitative easing policies and exchange rates". *Journal of Monetary Economics 117*, 489–506.

Dell'Ariccia, Giovanni, Pau Rabanal, and Damiano Sandri (2018). "Unconventional monetary policies in the Euro Area, Japan, and the United Kingdom". *Journal of Economic Perspectives 32* (4), 147–172.

Droste, Michael, Yuriy Gorodnichenko, and Walker Ray (2021). "Unbundling Quantitative Easing: Taking a Cue from Treasury Auctions". *Working Paper, University of California Berkeley*.

Duffie, Darrell (1999). "Credit Swap Valuation". *Financial Analysts Journal 55* (1), 73–87.

Fontana, Alessandro and Martin Scheicher (2016). "An analysis of euro area sovereign CDS and their relation with government bonds". *Journal of Banking and Finance 62*, 126–140.

Fratzscher, Marcel, Marco Lo Duca, and Roland Straub (2016). "ECB Unconventional Monetary Policy Actions: Market Impact, international Spillovers and Transmission Channels". *IMF Economic Review 64* (1), 36–74.

Gambetti, Luca and Alberto Musso (2020). "The effects of the ECB's expanded asset purchase programme". *European Economic Review 130*.

Georgiadis, Georgios and Johannes Gräb (2016). "Global financial market impact of the announcement of the ECB's asset purchase programme". *Journal of Financial Stability 26*, 257–265.

Glick, Reuven and Sylvain Leduc (2018). "Unconventional monetary policy and the dollar: conventional signs, unconventional magnitudes". *International Journal of Central Banking 14*, 103–152.

Greenlaw, David, James D Hamilton, Ethan Harris, and Kenneth West (2018). "A Skeptical View of the Impact of the Fed's Balance Sheet". *NBER Working Paper No. 24687, National Bureau of Economic Research*.

Gürkaynak, Refet S, Brian Sack, and Eric T. Swanson (2005a). "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements". *International Journal of Central Banking 1*, 55–93.

Gürkaynak, Refet S, Brian Sack, and Eric T. Swanson (2005b). "The Sensitivity of Long-Term Interest Rates to Economic News : Evidence and Implications for Macroeconomic Models". *American Economic Review 95* (1), 425–436.

Hachula, Michael, Michele Piffer, and Malte Rieth (2020). "Unconventional monetary policy, fiscal side effects, and euro area (im) balances". *Journal of the European Economic Association 18* (1), 202–231.

Hammermann, Felix, Kieran Leonard, Stefano Nardelli, and Julian von Landesberger (2019). "Taking stock of the Eurosystem's asset purchase programme after the end of net asset purchases". *ECB Economic Bulletin Articles, European Central Bank*.

Jarociński, Marek (2021). "Central Bank Information Effects and Transatlantic Spillovers". *ECB Working Paper No. 2482, European Central Bank*.

Jarociński, Marek and Peter Karadi (2020). "Deconstructing monetary policy surprises—the role of information shocks". *American Economic Journal: Macroeconomics 12* (2), 1–43.

Jordà, Òscar (2005). "Estimation and Inference of Impulse Responses by Local Projections". *American Economic Review 95* (1), 161–182.

Kerssenfischer, Mark (2019). "Euro Area Monetary Policy Effects : New Evidence from High-Frequency Futures Data". *Deutsche Bundesbank Discussion Paper No 07/2019, Bundesbank*.

Koijen, Ralph, François Koulischer, Benoît Nguyen, and Motohiro Yogo (2021). "Inspecting the mechanism of quantitative easing in the euro area". *Journal of Financial Economics 140* (1), 1–20.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen (2011). "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy". *Brookings Papers on Economic Activity 2011* (2), 215–287.

——— (2012). "The Aggregate Demand for Treasury Debt". *Journal of Political Economy 120* (2), 233–267.

Krishnamurthy, Arvind, Stefan Nagel, and Annette Vissing-Jorgensen (2018). "ECB Policies Involving Government Bond Purchases: Impact and Channels". *Review of Finance 22* (1), 1–44.

Kroencke, Tim A, Maik Schmeling, and Andreas Schrimpf (2021). "The FOMC risk shift". *Journal of Monetary Economics 120*, 21–39.

Lewis, Daniel (2019). "Announcement-Specific Decompositions of Unconventional Monetary Policy Shocks and Their Macroeconomic Effects". *Working Paper, Federal Reserve Bank of New York*.

Liu, Ernest, Atif R. Mian, and Amir Sufi (2019). "Low Interest Rates, Market Power, and Productivity Growth". *NBER Working Paper No. 25505, National Bureau of Economic Research*.

Lloyd, Simon P. (2021). "Overnight indexed swap-implied interest rate expectations". *Finance Research Letters 38*, 101430.

Nagel, Stefan (2016). "The liquidity premium of near-money assets". *Quarterly Journal of Economics 131* (4), 1927–1971.

Nakamura, Emi and Jon Steinsson (2018). "High Frequency Identification of Monetary Non-Neutrality: The Information Effect". *Quarterly Journal of Economics 133* (3), 1283–1330.

Ramey, Valerie (2016). "Macroeconomic Shocks and Their Propagation". *Handbook of Macroeconomics 2*, 71–162.

Rogers, John H, Chiara Scotti, and Jonathan H Wright (2014). "Evaluating asset-market effects of unconventional monetary policy: a multi-country review". *Economic Policy 29* (80), 749–799.

Schlepper, Kathi, Heiko Hofer, Ryan Riordan, and Andreas Schrimpf (2018). "The Market Microstructure of Central Bank Bond Purchases". *Journal of Financial and Quantitative Analysis*, 1–65.

Swanson, Eric T. (2021). "Measuring the effects of federal reserve forward guidance and asset purchases on financial markets". *Journal of Monetary Economics 118*, 32–53.

Swanson, Eric T. and John C Williams (2014a). "Measuring the Effect of the Zero Lower Bound on Medium-and Longer-Term Interest Rates". *American Economic Review 104* (10), 3154–3185.

Swanson, Eric T. and John C. Williams (2014b). "Measuring the effect of the zero lower bound on yields and exchange rates in the U.K. and Germany". *Journal of International Economics 92*.

Wieladek, Tomasz and Antonio Garcia Pascual (2016). "The European Central Bank's QE: A New Hope". *CESifo Working Paper No. 5946, Center for Economic Studies and Ifo Institute (CESifo) Munich*.

Wright, Jonathan H. (2012). "What does monetary policy do to long-term interest rates at the zero lower bound?" *Economic Journal 122* (564), 447–466.

Zhang, Donghai (2019). "Term Structure, Forecast Revision and the Information Channel of Monetary Policy". *Working Paper, University of Bonn*.

Appendices

A Factor Shocks

Throughout the paper, I use data up until January 31, 2020. This sample selection aims to exclude the COVID-19 crisis from the main analysis. An extended sample including the COVID-19 period is considered in Appendix F.

Updated Factors. To be able to use the entire sample, I re-estimate the factors of Altavilla et al. (2019) in this longer sample and use these updated series throughout the paper. I confirm that the original and re-estimated factors align very well in the original sample (01/2002 - 09/2018). The correlation coefficients exceed 0.995 for all three conference factors.

Policy & Information Shocks. I identify policy and information shocks using the rotational sign restriction approach used in Jarociński and Karadi (2020) and as implemented in Jarociński (2021). I use the monetary event window surprises in the period during which the QE factor is active (01/2014 - 01/2020). I choose as interest rate measure the first principal component of the standardized 1Y, 2Y, 5Y, and 10Y OIS rate surprises, since shorter-horizon OIS rates were severely constrained by the ELB. I use all three options to compute information shocks explained in Jarociński (2021). The easiest approach are the "poor man's sign restrictions". Here, interest rate surprises are classified as policy (information) shocks if the stock market surprise has the opposite (same) sign. The other two options explain the interest rate and stock price surprise with two factors. The sign restriction provides a set of admissible rotations of the two factors. Then, there are two options to choose

the rotation among all admissible rotations. The first option is use the rotation which ensures that the variance share of interest rate surprises explained by information shocks is the same as when using poor man's shocks. I follow Jarociński (2021) and use this as a baseline. The other option is to use the median rotation among all admissible rotations, as used in Andrade and Ferroni (2021). More details can be found in the Appendix of Jarociński (2021).

B Persistence of Impact Effects

The estimated impact effects on financial variables might have a reduced relevance for the real economy, if they are not persistent. For example, financial markets could overreact to asset purchase news initially. Several studies, including Wright (2012), Rogers et al. (2014), and Greenlaw et al. (2018), argue that this was the case for the Federal Reserve's Quantitative Easing programs.

To evaluate the persistence of the impact effects of asset purchase news, I use the same event-study regression as before, but replace the one-day change as the outcome variable with the h-day change for horizons h between 0 and 30. These are essentially Jordà (2005) local projections:

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h s_t + \epsilon_{h,t}$$

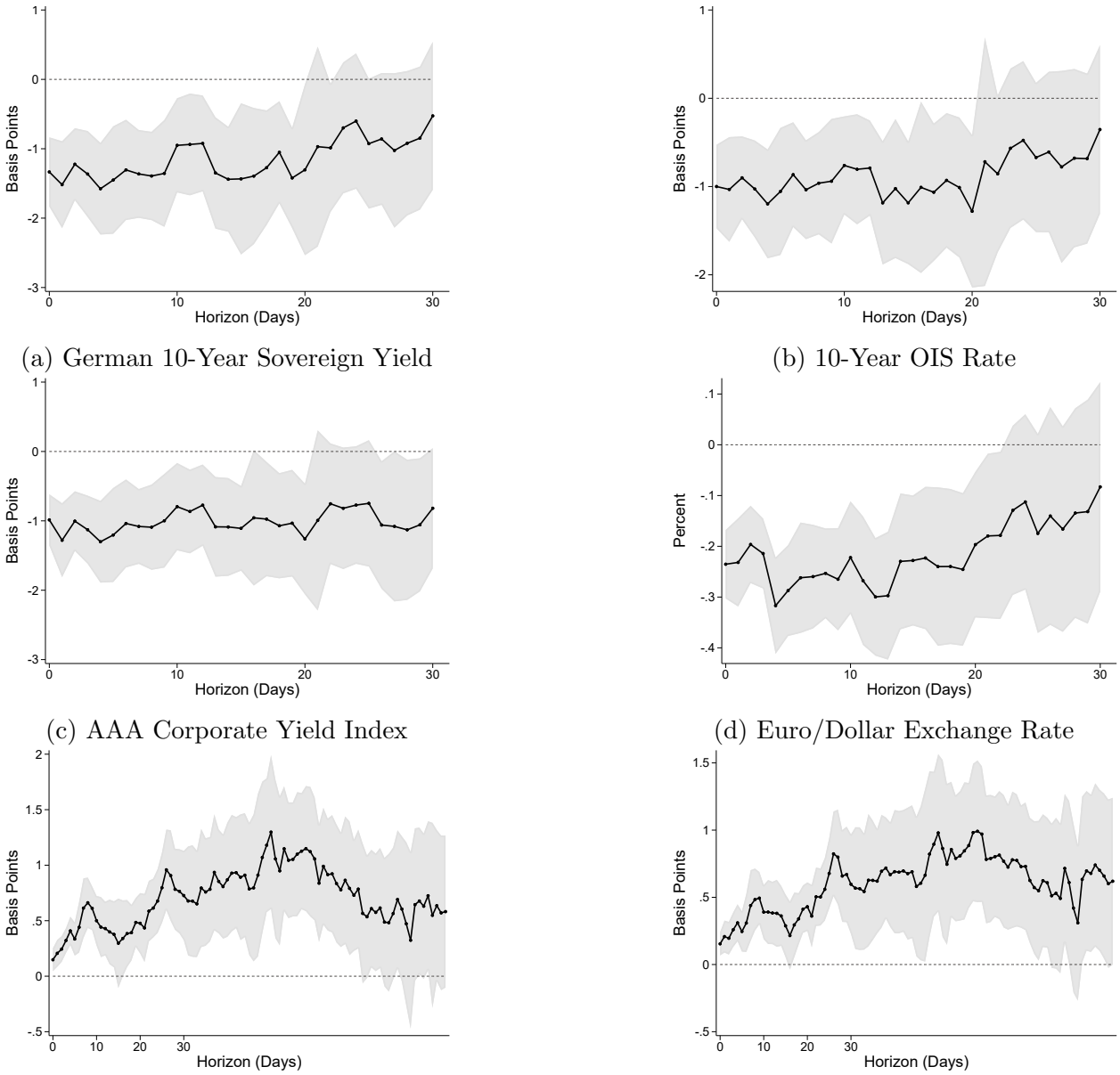
The parameter of interest is β_h, which captures the cumulative effect of asset purchase news over h trading days[47].

Figure A.1 shows the effect of asset purchase news over a horizon of 30 days on the German 10-year sovereign yield, the 10-year OIS rate, the AAA corporate yield index, the Euro/Dollar exchange rate, the DAX stock index and the STOXX50 stock index. Overall, the impact effects are fairly persistent and remain significant for quite some time. Confidence intervals naturally widen due to the amount of noise accumulating over 30 trading days. This is in contrast to the U.S. evidence and more in line with Altavilla et al. (2019), who also find the announcement effects of QE in the euro area to be rather persistent. These disparate findings in euro area and U.S. can be explained by market participants learning about the effects of asset purchases over time, or the fact that the Federal Reserve's programs were implemented in times of higher financial distress.

C Macroeconomic Data Releases

A number of studies, including Gürkaynak et al. (2005b), Swanson and Williams (2014a) and Swanson and Williams (2014b), have shown that the surprise component of macroeconomic

[47]Days without trading, such as weekends and public holidays are excluded.



(a) German 10-Year Sovereign Yield

(b) 10-Year OIS Rate

(c) AAA Corporate Yield Index

(d) Euro/Dollar Exchange Rate

(e) German Stock Index (DAX)

(f) STOXX50 Index

Figure A.1: Persistence of Impact Effects

Notes: The dots represent the estimated $\hat{\beta}_h$ from separate regressions: $y_{t+h} - y_{t-1} = \alpha_h + \beta_h s_t + \epsilon_{h,t}$, where the left-hand side is the change over h days, measured in basis points or percent, respectively. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Shaded areas depict the 90% confidence interval using standard errors robust to heteroskedasticity and autocorrelation.

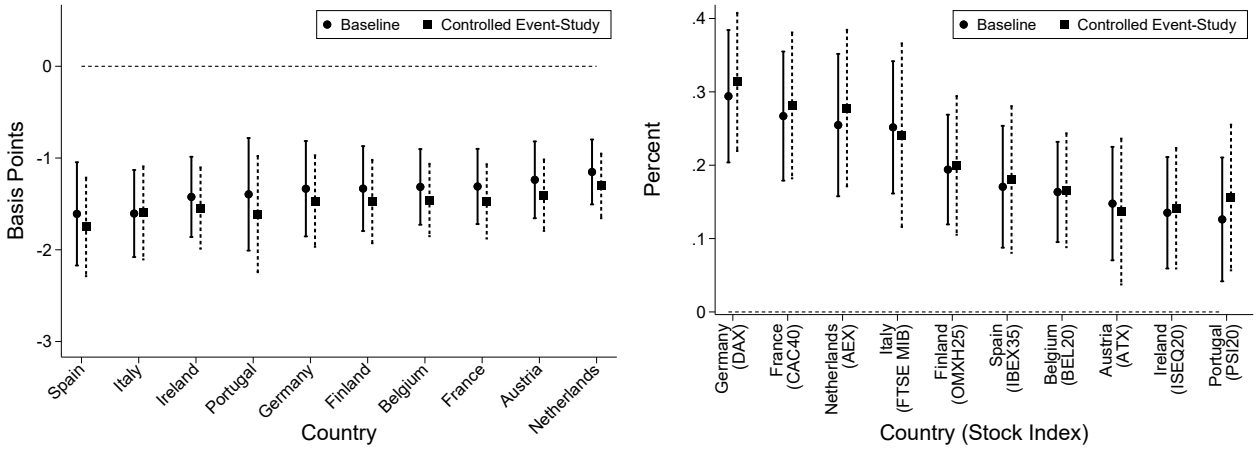
data releases has the potential to move long-term bond yields. These surprises, also referred to as "macroeconomic news", provide information about the state of the economy. Positive news typically lift interest rate expectations, in line with the notion that the central bank will eventually tighten its policy. In view of the sovereign bond yield decomposition of section

2, bond yields should rise accordingly. Beyond their effect on risk-free interest rates, it is possible that some macroeconomic news also affect the (expected) demand and supply for sovereign debt, thereby affecting the scarcity premium. In this section, I discuss the concern that macroeconomic releases coinciding with ECB Governing Council Meeting days might affect either the measure of asset purchase news or any results.

For this purpose, I retrieve data on macroeconomic releases from Bloomberg. I include all country-specific data releases for the ten largest euro-area countries as well as euro-area-wide data releases with a nonzero relevance for financial markets. Moreover, I include the 40 U.S. data releases with the highest relevance for financial markets. I drop observations where there were less than 8 participants in the pre-release survey. Then, I drop all series for which less than 10 observations remain in total. This leaves a total of 102 series from the euro area and 37 from the U.S.. I compute the surprise as the difference between the actual value and the survey median.

Macroeconomic releases occurring during the high-frequency window on ECB GCM days could in principle affect the scarcity premium and thus the series of asset purchase news. There is one important data release, which frequently coincides with the ECB communication on GCM days, namely the U.S. initial jobless claims (IJC). However, the correlation of IJC surprises and asset purchase news is small and insignificant (ρ=0.15, p-value=0.3444, N=41). Macroeconomic releases occurring outside the high-frequency window, but on ECB GCM days, cannot affect the measured yield and OIS rate surprises, but could still affect the (daily) CDS surprises used for the construction of the asset purchase news. There are no data releases (except for the IJC) which regularly coincide with ECB GCM days, however, there are some releases which coincide a few (i.e. up to 7) times. To test whether this is a quantitatively relevant concern, I reconstruct the series of asset purchase news after orthogonalizing the CDS rate changes with respect to euro-area and U.S. macroeconomic surprises. The correlation of this series with the baseline series of asset purchase news is extremely high ($\rho = 0.975$). I conclude that there is no evidence that macroeconomic data releases affect the series of asset purchase news in a quantitatively relevant way.

However, given the limited sample size, even if macroeconomic news do not affect the series of asset purchase news, they might still affect the outcome variables and therefore the reported results. To rule out this concern, I perform a "controlled" event study in the spirit of Altavilla et al. (2016). That is, I re-estimate the effects of asset purchase news on sovereign yields and national stock indices controlling for all euro-area and U.S. surprises. The sample is October 1, 2014 until January 31, 2020. Figure A.2 displays the results. Evidently, the estimates of the effect of asset purchase news on sovereign yields and national stock indices do not change much when controlling for macroeconomic news.



(a) Sovereign Yields (b) National Stock Indices

Figure A.2: Robustness Exercise - Controlling for Macroeconomic News

Notes: The dots represent the baseline estimates as in figures 6 and 9. The squares represent the estimates controlling for macroeconomic surprises. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

D Aggregation of Asset Purchase News

The baseline series of asset purchase news is computed as the first principal component of the (standardized) series of scarcity premium changes around ECB communication on Governing Council Meeting days. This aggregated series is highly correlated with the country-specific series. The correlations are 0.85 (FR), 0.79 (IT), 0.77 (ES), and 0.70 (DE). This reassures that the final series indeed measures a common shock, which is reflected in each country-specific series.

Vice versa, no single country is driving the baseline series. This can be assessed by computing four series of "leave-one-out" asset purchase news, by leaving out one country at a time in the aggregation procedure. The correlation of these four series with the baseline series never falls below 0.96, reassuring that no single country is disproportionately affecting the aggregated series.

An alternative aggregation procedure would be to use a GDP-weighted average of unstandardized scarcity premium changes. This produces a remarkably similar series of asset purchase news, the correlation with the baseline series is 0.99. Practically, GDP-weighting and standardizing to unit variance do (almost) the same thing. Both reduce the influence of the Italian and the Spanish series, because these countries have the lowest GDP and also the highest variance of scarcity premium changes.

E Liquidity in CDS Markets

A potential concern with the identification strategy is that the market for CDS contracts is not as liquid as the markets for sovereign debt and OIS contracts. This potentially makes the scarcity premium reflect changes in the country-specific risk premium. As an example, if central bank communication changes the risk premium and this is correctly priced in sovereign yields, while CDS rates do not change because of illiquidity, the scarcity premium will reflect the change in the risk premium.

However, using a longer window (daily) for CDS surprises than for sovereign yield and OIS rate surprises (high-frequency), as discussed in section 2, mitigates this concern to some extent. In addition, judging by the number of missing observations over the entire sample period, the CDS contracts for Italy and Spain (the countries with higher and more volatile CDS rates and generally more concern about sovereign risk) are relatively more liquid.

As a robustness check, I re-construct the series of asset purchase news using CDS contracts denominated in U.S. Dollar instead of those denominated in Euro, since USD CDS are typically more liquid than Euro CDS. Of course, USD CDS rates depend on the exchange rate, which is itself affected by monetary policy. For this reason, the baseline series uses Euro CDS. Nevertheless, the series of USD-CDS asset purchase news is highly correlated (ρ=0.94) with the baseline series of asset purchase news, suggesting that CDS illiquidity is not a major concern for the identification strategy.

F Extended Sample

The baseline sample used throughout this paper includes all ECB Governing Council Meetings between October 2014 and January 2020 (N=44). In this section, I show how the results are affected if this sample is extended.

The baseline sample begins in October 2014, because CDS contracts based on the 2014 ISDA Credit Derivatives Protocol are traded since September 22, 2014. These contracts insure against sovereign default and currency redenomination. CDS contracts under the previous 2003 ISDA Credit Derivatives Protocol do not insure against currency redenomination for G-7 countries (including Germany, France and Italy). Thus, before October 2014, it is not possible to separate the scarcity premium from a *redenomination risk premium* for these three countries. In consequence, a stronger identifying (exogeneity) assumption is needed. That is, one has to assume that all elements of ECB communication, except for asset purchase news, do not affect the redenomination risk premium. To avoid having to make this assumption, the baseline sample begins in October 2014, when CDS contracts based

on the 2014 ISDA protocol become available. However, bearing the caveat in mind, it is of course possible to extend the series of asset purchase news backwards using CDS contracts under the 2003 ISDA protocol. This could be interesting because, even though the PSPP was officially announced in January 2015, expectations about large-scale asset purchases in the euro area started to form before October 2014. For example, Mario Draghi's speech at the Jackson Hole Symposium in August 2014 is often considered as having signaled that large-scale asset purchases are possible in the future.

The baseline sample ends in January 2020 with the last Governing Council Meeting before the COVID-19 crisis. The current release of the EA-MPD includes 3 additional Governing Council Meetings, so it is possible to extend the sample until June 2020. This could be interesting in order to see whether the identification strategy also works for the Pandemic Emergency Purchase Programme (PEPP). The reason not to include these three observations in the main analysis is that the PSPP and the PEPP are programs with very different intentions. The PSPP was intended to stimulate inflation and growth in the euro area as a whole. Thus, it did not intend to have heterogeneous effects across countries. The PEPP instead was primarily intended to mitigate concerns about sovereign debt sustainability in some euro-area countries. Therefore, even though purchases remained proportional, there was a relatively clear heterogeneous intention, as in some countries, there was a lot more concern about sovereign debt (e.g. Italy, Spain) than in others (e.g. Germany). Thus, focusing on the PSPP in the baseline sample provides a nice setting to analyze how asset purchases intended to stimulate economic activity work in times of low financial distress.

Figure A.3 plots the series of asset purchase news for the baseline sample and an "extended" sample from January 2014 to June 2020. Evidently, shocks identified between October 2014 and January 2020 barely change. Before October 2014, there is one relatively large contractionary realization in April 2014, which is indeed one of the Governing Council Meetings where QE was discussed.[48] After January 2020, there is one relatively large expansionary realization in June 2020, which is also in line with the financial press.[49]

Figure A.4 shows that the effect of asset purchases on euro-area sovereign yields and national stock indices remains largely unchanged in the extended sample, as long as the March 2020 Governing Council Meeting remains excluded. Including this date changes the magnitude of the coefficients for Italian sovereign yields as well as for stock prices, even though the measure of asset purchase news on this date is small (and negative). The reason is that outcome variables, in particular the Italian 10-year sovereign yield and all stock

[48] e.g. https://www.reuters.com/article/markets-forex-idUSL1N0MV1A720140403

[49] e.g. https://www.cnbc.com/2020/06/04/european-central-bank-ramps-up-its-pandemic-bond-buying-to-1point35-trillion-euros.html

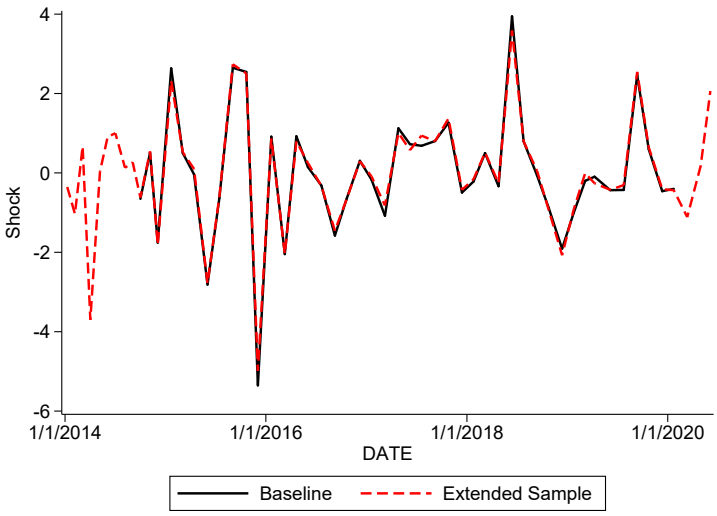
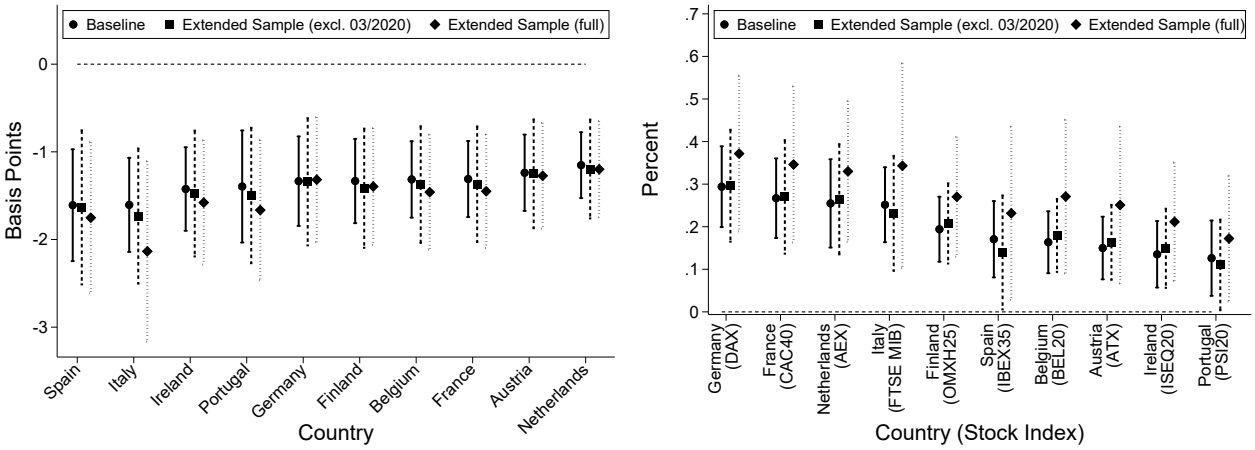


Figure A.3: Series of Asset Purchase News (Baseline & Extended Sample)

indices, moved dramatically in consequence of the comment made by President Lagarde that the ECB is "not here to close spreads". This event fits the interpretation of a "risk shock" (Kroencke et al., 2021), since sovereign yields moved a lot, driven by sovereign risk premiums. Scarcity premiums increased a bit, in line with the interpretation that this event constituted rather contractionary asset purchase news. Either way, the main qualitative results of heterogeneous effects on stock indices and a lack of a significant effects on sovereign yield spreads vis-à-vis Germany, remain unchanged also in the full extended sample.



(a) Sovereign Yields

(b) National Stock Indices

Figure A.4: Robustness Exercise - Extended Sample

Notes: The dots represent the baseline estimates as in figures 6 and 9. The squares represent the estimates in the extended sample, excluding the March 2020 GCM. The diamonds represent the estimates from the full extended sample. Whiskers depict the 90% confidence intervals using standard errors robust to heteroskedasticity.

Additional Figures

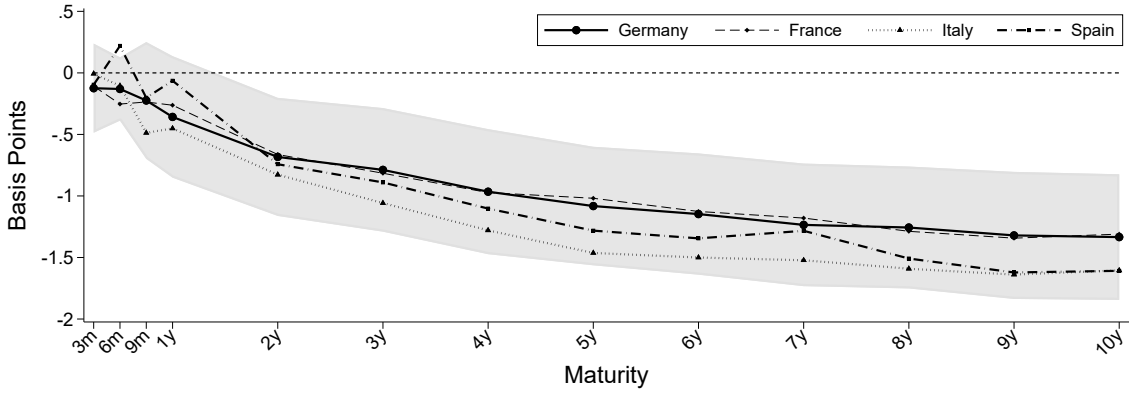


Figure A.5: Response of Euro-Area Sovereign Yields to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. Shaded areas depict the 90% confidence interval using standard errors robust to heteroskedasticity for German sovereign yields.

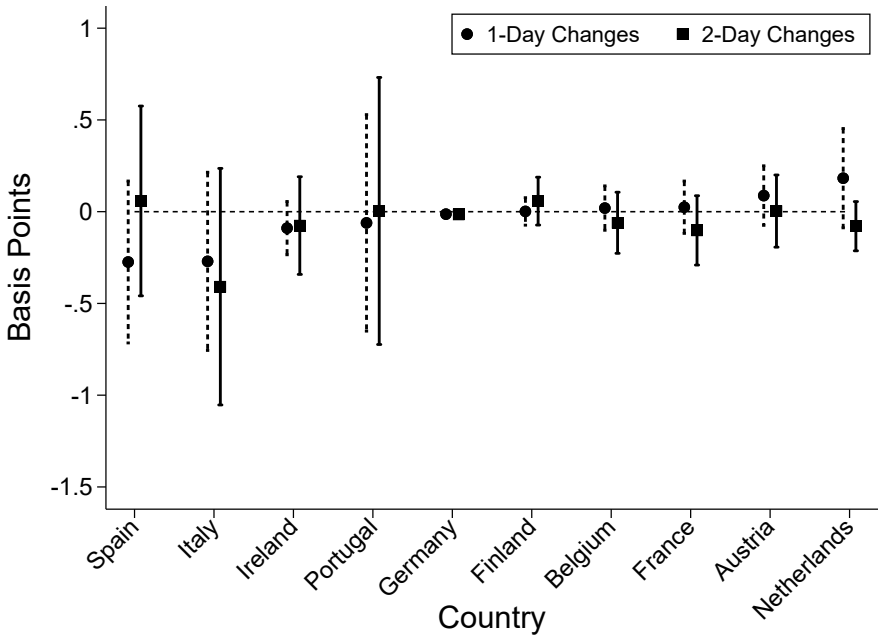


Figure A.6: 10-Year Sovereign Spreads (vis-a-vis Germany) to Asset Purchase News

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

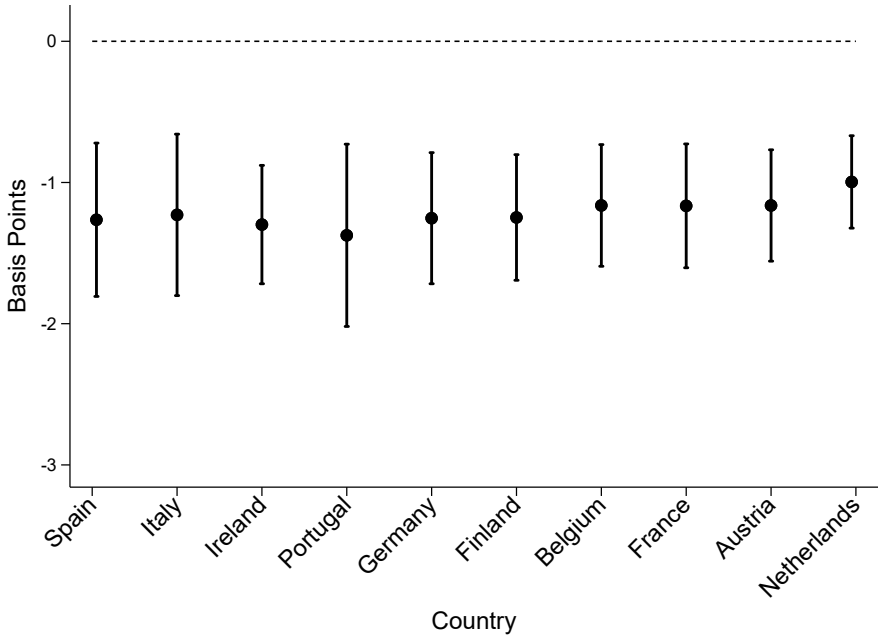


Figure A.7: Response of 10-Year Euro-Area Sovereign Yields to QE Factor

Notes: The dots represent the estimated $\hat{\beta}$ from separate regressions: $y_t = \alpha + \beta s_t + \epsilon_t$, where y_t is the daily change, measured in basis points. Shocks are scaled to reduce the 10-year OIS rate by one basis point. Whiskers depict the 90% confidence interval using standard errors robust to heteroskedasticity.

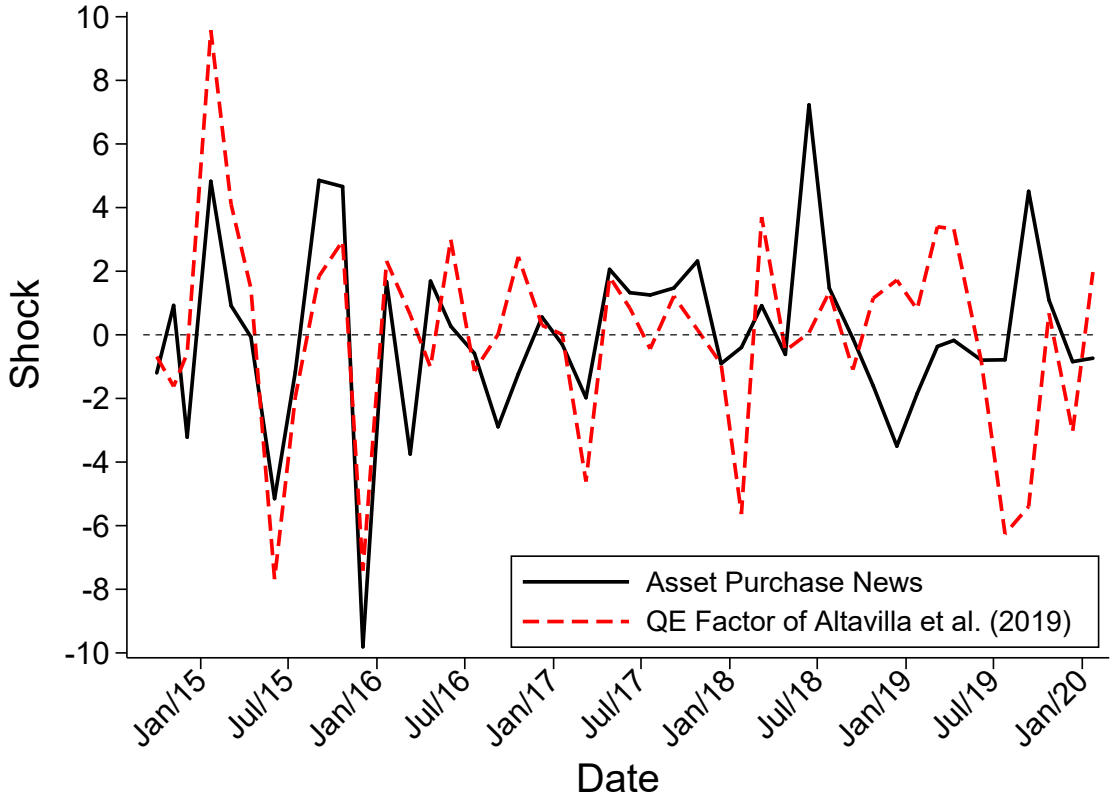


Figure A.8: Series of Asset Purchase News & QE Factor of Altavilla et al. (2019)

Notes: Both series are scaled to reduce the 10-year OIS rate by one basis point. Sample: October 2014 - January 2020 (N=44).