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Abstract

We conduct the most extensive study of underpricing in the euro area bond market so far and find strong evidence of underpricing. In cross-sectional regressions we find patterns that are consistent with bookbuilding-based theories of underpricing and inconsistent with liquidity-based explanations. The underpricing has increased considerably during the financial crisis and has remained at an elevated level since. We also show that secondary market liquidity in the euro area bond market is significantly lower in the post-crisis period than pre-crisis. These results are consistent with recent US evidence and may represent unintended side effects of new regulation enacted in the wake of the financial crisis, such as Basel III and the Volcker Rule. Furthermore, our evidence suggests that the ECB's asset purchase programs have led to a decrease in underpricing.

JEL-Classification: G12, G32, E58
Keywords: Underpricing, Bond Markets, Primary Market, Post-Crisis Regulation, ECB, Unconventional Monetary Policy, Quantitative Easing, Asset Purchase Programs

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1. Introduction

In this paper we provide evidence that bond issues in the euro area are systematically underpriced. We analyze the determinants of underpricing and obtain results that are consistent with information-based explanations in general and bookbuilding theories of underpricing (such as Benveniste and Spindt, 1989) in particular, but which are inconsistent with liquidity-based explanations. We also show that underpricing has increased considerably during the financial crisis and has remained at an elevated level since. Further, we show that, consistent with recent US evidence, secondary market liquidity in the euro area bond markets is significantly lower in the post-crisis period than pre-crisis, possibly because of new regulation enacted in the wake of the financial crisis. Finally, we demonstrate that the European Central Bank's asset purchase programs have led to a decrease in underpricing.

Bond underpricing directly contributes to the borrowing costs of issuers. Against the backdrop of the huge volume of the bond markets even modest underpricing sums up to large amounts of money left on the table. It is therefore important to understand the magnitude and determinants of underpricing. Recent regulatory changes that were implemented in the wake of the financial crisis, such as the Basel III accord or the Dodd Frank act in the U.S., may have effects on the pricing of bonds and the borrowing conditions of euro area bond issuers. The regulations may affect the willingness of underwriters and market makers (which often are the same institutions for a given bond issue) to commit capital to the issuing process and subsequent market making activities in the secondary market. This, in turn, may affect the liquidity and pricing of bonds. Similarly, the European Central Bank's asset purchase programs, a component of its unconventional monetary policy, entail direct interventions in the primary and secondary markets for bonds and may therefore affect bond pricing as well.

We compile a sample of more than 5,700 Euro-denominated bonds issued by financial and non-financial corporations and by supranational organizations and agencies between 2002 and 2017 and analyze the magnitude of underpricing using event study methodology. Specifically, we consider the abnormal bond return during the first 40 days of secondary market trading. If a bond issue is underpriced these abnormal returns are expected to be positive. We further analyze the determinants of corporate bond underpricng using cross-sectional regressions. The implications on bond underpricing of the European Central Bank's asset purchase programs are analyzed using a difference-in-differences approach.

It is a stylized fact, known at least since the 1970s, that IPOs of US corporate bonds are underpriced, just as equity IPOs are. Ederington (1974) and Lindvall (1977) find that the yield to maturity (YTM) of newly issued bonds is higher than the YTM of seasoned bonds, a finding implying underpricing of bonds. Weinstein (1978) considers holding period returns instead of YTMs and also finds evidence of underpricing. Subsequent research has confirmed this general finding (e.g. Sorensen, 1982; Hale and Santos, 2006; Cai et al., 2007; Goldstein and Hotchkiss, 2012; Goldberg and Ronn, 2013; Liu and Magnan, 2014; Helwege and Wang, 2016; Nagler and Ottonello, 2017).[1] Results for non-US markets are sparse and are based on rather small samples (the maximum number of bond issues in a sample being 328) but are also supportive of underpricing (Wasserfallen and Wydler, 1988 for Switzerland, Zaremba, 2014 for Central and Eastern European countries, Aronsson and Tano, 2016 for Sweden and Mietzner et al., 2016 for Germany).

Theories of underpricing in bond markets can broadly be categorized into information-based and liquidity-based approaches (Cai et al., 2007; Brugler et al., 2016). Information-based approaches posit that underpricing is a compensation for the winner's curse risk (Rock, 1986), a compensation paid to investors who supply information to the underwriters during the bookbuilding process (Benveniste and Spindt, 1989; Sherman and Titman, 2000), or a costly signal (Allen and Faulhaber, 1989; Welch, 1989). Liquidity-based explanations, in contrast, argue that expected secondary market liquidity affects the pricing in the primary market (Booth and Chua, 1996; Ellul and Pagano, 2006).

Several papers contend that new regulations enacted after the financial crisis, such as the Basel III accord, the Dodd Frank act in the US, or the measures proposed in the Liikanen report, have reduced the amount of capital dealers are willing to commit to their market making activities in the bond markets (Bao et al., 2017; Bessembinder et al., 2017; Dick-Nielsen and Rossi, 2016; Duffie, 2012). Usually the financial institutions that underwrite a corporate bond issue also act as market makers in the secondary market (International Capital Market Association, 2016; Nagler and Ottonello, 2017). It is therefore conceivable that the new regulations also affect the behavior of underwriters in the primary market and, consequently, the pricing of new bond issues. In fact, Nagler and Ottonello (2017) argue that the post-crisis regulation provides incentives for underwriters to allocate bonds to closely affiliated investors, and that this practice has contributed to larger underpricing

[1] Notable exceptions are Fung and Rudd (1986) and Datta et al. (1997). Both papers do not find evidence of underpricing on average. Datta et al. (1997) subdivide their sample and find that high yield bond issues are underpriced while investment grade bond IPOs are *over*priced.

of corporate bonds in the US.

In the wake of the financial crisis central banks have increased the menu of policy instruments they choose from (e.g. Joyce et al., 2012). Specifically, they have engaged in Quantitative Easing (QE). Starting in 2009, the European Central Bank has initiated several asset purchase programs in the course of which the bank bought bonds meeting certain eligibility criteria. Several papers (e.g. Abidi and Flores, 2018; Markmann and Zietz, 2017; Lamoen et al., 2017; Gürtler and Neelmeyer, 2018) have shown that these programs were effective in significantly decreasing the yield spreads of eligible bonds. None of these papers analyzes whether the programs also affect the initial underpricing of the bonds.

Our paper makes five contributions to the literature. First, it is by far the most comprehensive study of bond underpricing in Europe, both in the cross-sectional dimension and in the time-series dimension. Second, we analyze the cross-sectional determinants of bond IPO underpricing. Our results support the predictions obtained from bookbuilding-based theories of underpricing (e.g. Benveniste and Spindt, 1989) but are inconsistent with liquidity-based explanations. We thus confirm Cai et al. (2007) and Brugler et al. (2016) who also favor information-based explanations of bond IPO underpricing. Third, we are the first to document that the underpricing of euro area bonds has increased considerably during the financial crisis and has remained above the pre-crisis level since, thereby confirming the results Nagler and Ottonello (2017) obtained for the US market. Fourth, and also consistent with the recent US evidence, we demonstrate that the liquidity of the euro area secondary bond markets in the post-crisis period is significantly lower than the pre-crisis liquidity, possibly because of the regulatory changes enacted after the crisis. Finally, ours is the first paper to analyze the implications on bond IPO underpricing of central bank interventions in the corporate bond market, thus contributing to a better understanding of the effects of quantitative easing.

While some of the questions we address have been studied in the context of the US market we believe that an analysis of the euro area is important in its own right. The regulatory environment is different from the US, and the financial systems of the majority of the euro area member states are bank-dominated rather than market-dominated. Further, the creation of the monetary union has resulted in an increasing level of market integration, a higher number of corporate bond issues, and more liquid secondary markets (Pagano and von Thadden, 2004).

The remainder of the paper is organized as follows. In Section 2 we describe the institutional background. Section 3 develops the hypotheses. Section 4 describes the data and methodology. The results are presented in Section 5. Section 6 concludes.

2. Institutional Background

2.1. The Primary Market for Corporate Bonds

The standard for the issuance of corporate bonds in Europe has been set by the International Capital Market Association (ICMA), a self-regulatory organization with more than 500 members, among them issuers, financial intermediaries and asset management firms. ICMA characterizes the primary market for corporate bonds and its pre-dominant issuance process, the bookbuilding method, as follows:

> *"The primary market for corporate bonds is where the bond is created and initially sold to investors. Usually the corporate issuer will appoint a bank (or banks) as a lead manager, who will provide advice on the optimal timing, structure, and pricing of the issuance, as well as building a syndicate of other banks, all of whom will look to build investor interest in purchasing the bonds (known as 'book building'). Banks may also provide an 'underwriting' service, where they agree to take any unsold bonds onto their own books to hold or subsequently trade in the secondary market."* (International Capital Market Association, 2014, p. 7)

Two specific features of the issuing process are of particular importance. First, it is very common that the underwriters of a bond issue in the primary market subsequently also act as market makers in the secondary market:

> *"Usually, market-makers in a particular bond are the same banks who are involved in the primary issuance of that bond, with secondary market-making being part of the 'pitch' to the corporate issuer to win the origination mandate, and as a component of the overall service package."* (International Capital Market Association, 2016, p. 9)

Nagler and Ottonello (2017, p. 6), who discuss the institutional details of corporate bond issues in the US, conclude that *" [...] in shaping the initial allocation of bonds*

they [the underwriters] can take into account their future role as dealers in the secondary market".

Second, underwriters in the primary market for corporate bonds have more discretion in allocating bonds to investors than underwriters in the equity market (e.g. Levin, 2014; Nagler and Ottonello, 2017). In particular, they can also keep bonds on their own inventories.

2.2. The Post-Crisis Regulatory Regime

In the wake of the financial crisis the regulation of the financial sector has been tightened. In the US, the Volcker Rule - as part of the Dodd Frank Act - restricts proprietary trading as well as the ownership of hedge funds (which may also act as liquidity providers in bond markets). It includes exemptions for market-making activities. However Duffie (2012) analyzes these exemptions and concludes that *"[t]his attempt to disentangle those trades that have market making intent from those that do not is likely to be effective only in reducing the capacity of market making services provided by banks."* (Duffie, 2012, p. 22). Consistent with this view, Bao et al. (2017) and Bessembinder et al. (2017) find that the Volcker rule has negatively affected bond market liquidity.

The Volcker rule does not affect bond issuing in Europe directly, but may affect it indirectly for three reasons. First, European banks may comply with US rules in order to do business overseas. Second, US banks comply with US rules but also underwrite Euro-denominated bonds. Third, the European Commission published the Liikanen Report which recommends regulation similar to the Volcker Rule. These recommendations have largely been included in the proposals for the EU's Bank Structural Reform. Although the proposals are still under review, banks may already adjust their market making activities in anticipation of the new rules.

Also in response to the financial crisis, the members of the Basel Committee on Banking Supervision agreed upon the Third Basel Accord (Basel III) in 2010. It will come into force in several steps until 2019 and is intended to strengthen bank capitalization and bank solvency. Primary market activities may be affected for two reasons. First, because market-making activities are part of the overall service package of underwriters, the pricing of new issues in the primary market may be affected by changes in expected profits from underwriters' market making activities in the secondary market. Second, Basel III will increase the capital requirement (and, consequently, the costs) for the underwriters of

holding unsold bonds in their inventories. This, in turn, may affect the pricing of issues in the primary market.

The facts that the new regulation was not announced on a single, identifiable announcement date, that some of the new rules came into force in a stepwise manner, that some deadlines have been extended, and that underwriters adjusted their operations already in anticipation of the new rules makes it difficult to perform a difference-in-differences analysis. We therefore follow previous papers (e.g. Bao et al., 2017; Bessembinder et al., 2017; Nagler and Ottonello, 2017) and subdivide our sample period into a pre-crisis period (January 1, 2002 until June 30, 2007), a crisis period (July 1, 2007 until March 31, 2009) and a post-crisis period (April 1, 2009 until the end of the sample period).[2]

2.3. The ECB's Asset Purchase Programs

As a component of its QE policies the European Central Bank (ECB) has initiated several asset purchase programs (APP). These were aimed at the propagation of the low money market rates, the easing of funding conditions for financial institutions and the corporate sector, the encouragement of banks to increase their lending activities, and the improvement of market liquidity.

The first APP, the covered bond purchase program (CBPP1), was active between July 2, 2009 and June 30, 2010. Its total notional volume amounted to 60 billion EUR.[3] The main eligibility criteria have been as follows (European Central Bank, 2009):

- The issuer is incorporated in the euro area.
- The issue is EUR-denominated.
- The issue is held and settled in the euro area.
- The issue fulfills Article 22(4) of the UCITS Directive or similar.
- The issue size is >100 million EUR.
- The issue has a minimum rating of "AA" or equivalent by at least one of four eligible rating agencies (Fitch, Moody's, S&P and DBRS).

[2] The exact start date and duration of the crisis are debatable. The beginning of the crisis is often dated to August 9, 2007 when BNP Paribas closed three of their collateralized debt obligation (CDO) funds. The end of the crisis is often dated to March 9, 2009 when the Dow Jones Industrial Index reached a 12-year low (and subsequently recovered). The Federal Reserve dates the recession (as inferred from GDP data) as lasting from Q4/2007 to Q2/2009. Considering these dates, and taking into account that GDP-based measures may lag the capital markets, we consider Q3/2007 until Q1/2009 as a reasonable definition of the crisis period. Our definition is almost identical to the one used by Bao et al. (2017) and Bessembinder et al. (2017) who both define the crisis period to be July 1, 2007 to April 30, 2009.

[3] The ECB did not disclose the volume of purchases in the primary and secondary market separately.

- The issue is pursuant to legislation governing covered bonds that is in force in a euro area member state.

The second covered bond purchase program (CBPP2) was active between November 3, 2011 and October 31, 2012. Its total volume amounted to 16.4 billion EUR of which 36.7% have been purchased in the primary market. As compared to CBPP1, the main changes in the eligibility criteria were (European Central Bank, 2011):

- The issue size is >300 million EUR.
- The issue has a minimum rating of "BBB-" or equivalent by at least one rating agency out of Fitch, Moody's, S&P and DBRS.
- The issue has a maximum remaining maturity of 10.5 years at the time of the purchase.

The third covered bond purchase program (CBPP3) was launched on October 15, 2014 and is still active. Its total volume (as of April 30, 2017) amounts to 214.4 billion EUR, of which 32.0% have been purchased in the primary market. The main changes in the eligibility criteria as compared to CBPP2 are (European Central Bank, 2014):

- The issue fulfills a 70% issue share limit[4] per ISIN to the joint holdings under the CBPP1, the CBPP2, and the CBPP3 and to the other holdings of Eurosystem central banks.
- The issue fulfills a 30% issue share limit per ISIN for covered bonds in Cyprus and Greece which do not achieve the Credit Quality Step 3 (CQS3) in the Eurosystem's harmonized rating scale.
- Entities suspended from Eurosystem credit operations are excluded from the CBPP3 for the duration of their suspension.
- Covered bonds retained by their issuer are explicitly stated to be eligible if the above criteria are fulfilled.

On March 4, 2015 the public sector purchase program (PSPP) was initiated. It was still active at the end of our sample period. Its notional volume as of April 30, 2017 amounted to 1,457.6 billion EUR, including both government bonds and bonds from government-related national and supranational institutions. Many of the bonds in the

[4] The issue share limit represents the maximum percentage of the notional amount of a bond that the ECB is allowed to hold. The limit is set per ISIN.

latter categories are subject to the institutional setting described in Section 2.1 and are therefore included in our sample. The main eligibility criteria for the PSPP are (European Central Bank, 2015):

- The issuer may be a central government of a member state whose currency is the Euro, a recognized agency located in the euro area, an international organization located in the euro area or a multilateral development bank located in the euro area.
- The issuer has a credit quality assessment of at least CQS3 in the Eurosystem's harmonized rating scale (including exceptions).
- The issue has a minimum remaining maturity of 2 years and maximum remaining maturity of 30 years.
- The issue fulfills a 25% issue share limit per ISIN.
- An aggregate limit of 33% of an issuer's outstanding securities applies.
- The PSPP may include public-sector non-financial corporations.
- The PSPP may include marketable debt instruments at a negative yield to maturity (or yield to worst) above the deposit facility rate.
- No purchases are permitted in a newly issued or tapped security.

On June 8, 2016 the ECB launched the corporate sector purchase program (CSPP) which also was still active at the end of our sample period. The total notional volume of this program as of April 30, 2017 amounted to 75.5 billion EUR, of which 13.9% have been purchased in the primary market. The main eligibility criteria of the CSPP are (European Central Bank, 2016):

- The issuer is incorporated in a member state whose currency is the Euro.
- The issuer is not (and does not have a parent which is)
  - a credit institution as defined in point (14) of Article 2 of Guideline (EU) 2015/510 (ECB/2014/60)
  - subject to banking supervision outside the euro area
  - a supervised entity or member of a supervised group according to the respective EU regulations
  - an investment firm or asset management vehicle or national asset management and divestment fund according to the respective EU regulations
  - an eligible issuer for the PSPP
- The issuer has not issued an asset-backed security or multi cédula or structured covered bond

- The issue has a minimum remaining maturity of 6 months and maximum remaining maturity of 30 years and 364 days.
- The issue is EUR-denominated.
- The issue has a minimum rating of "BBB-" or equivalent from at least one of the four rating agencies Fitch, Moody's, S&P and DBRS.
- The issue fulfills a 75% issue share limit per ISIN.
- The CSPP may include marketable debt instruments at a negative yield to maturity (or yield to worst) above the deposit facility rate.

Two differences between the APPs are particularly noteworthy in the context of our empirical analysis. First, the PSPP only allows purchases in the secondary market while the other programs allow primary market purchases as well. However, ECB purchases in the secondary market may affect prices and liquidity in the secondary market. This, in turn, may have repercussions on the primary market. We therefore include the PSPP in our analysis. Second, the ISINs of the bonds purchased under the PSPP and the CSPP are publicly disclosed while the ISINs of the covered bonds purchased under the CBPP1, the CBPP2 and the CBPP3 are not. Therefore, when analyzing the implications on underpricing of the covered bond purchase programs we can only differentiate between eligible and non-eligible bonds. When analyzing the PSPP and CSPP programs, on the other hand, we can identify those bonds that have actually been purchased. We do not know, though, which of the bonds bought under the CSPP were bought in the primary market.

3. Hypotheses

The available empirical evidence suggests that corporate bond issues are systematically underpriced (Ederington, 1974, Lindvall, 1977, Weinstein, 1978, Sorensen, 1982, Datta et al., 1997, Hale and Santos, 2006, Cai et al., 2007, Goldstein and Hotchkiss, 2012, Goldberg and Ronn, 2013, Liu and Magnan, 2014, Helwege and Wang, 2016, Nagler and Ottonello, 2017 for the US and Wasserfallen and Wydler, 1988, Zaremba, 2014, Aronsson and Tano, 2016 and Mietzner et al., 2016 for specific European countries). We therefore expect to find evidence of underpricing in our European sample.

H1: *On average, euro area bond issues are underpriced.*

Theories of underpricing based on informational asymmetries imply that the underpric-

ing is higher for more risky bonds, for bonds that are more difficult to value, and for issues exposed to higher levels of informational asymmetries (Cai et al., 2007). We thus have

H2: *The amount of underpricing is positively related to variables measuring the riskiness of the bond, the degree of uncertainty about the value of the bond, and the existence of informational asymmetries.*

During the financial crisis the uncertainty in financial markets has reached unprecendented levels. Therefore, an immediate corollary of hypothesis 2 is the following hypothesis.

H3: *The amount of underpricing is higher during the financial crisis.*

Benveniste and Spindt (1989) suggest that underpricing is a compensation for institutional investors who provide valuable information to the underwriter during the bookbuilding process. Cai et al. (2007) argue that this kind of information is less valuable when the same issuer has gone through a bookbuilding process recently, resulting in the following hypothesis.

H4: *Underpricing is lower for bonds issued by issuers who have gone through a bookbuilding process recently.*

Liquidity-based explanations imply that bond underpricing is a compensation for low expected secondary market liquidity of a bond. We therefore have

H5: *The amount of underpricing is increasing in the expected secondary market illiquidity of the bond.*

Nagler and Ottonello (2017) argue that the regulatory changes enacted after the financial crisis have resulted in a structural change in corporate bond markets. With respect to the primary market they contend that the post-crisis regulation provides incentives for underwriters to allocate bonds to closely affiliated investors, and that this practice has contributed to higher underpricing of corporate bonds in the US. Additionally, it has been argued that banks commit less capital to market making activities in the bond market (Bao et al., 2017; Bessembinder et al., 2017; Dick-Nielsen and Rossi, 2016; Duffie, 2012). The financial institutions that underwrite a corporate bond issue typically also act as market makers in the secondary market (International Capital Market Association, 2016; Nagler and Ottonello, 2017). Therefore, the regulatory changes may also affect the pricing of bonds in the primary market. Even though some of the new regulation only affects the US market directly, it may also have implications for European bond markets because (1)

European banks comply with US regulation when they do business in the US, (2) US banks comply with US regulation but also do business in Europe and (3) the Liikanen report proposes EU regulation similar to the Volcker rule in the US, and banks may comply with this rule in anticipation of its implementation. We therefore have the following hypothesis.

H6: *The level of underpricing in the post-crisis period is higher than in the pre-crisis period.*

The European Central Bank's asset purchase programs may affect bond underpricing through various channels. All programs except the PSPP allow primary market purchases by the ECB. The additional demand by the ECB may make it easier for underwriters to place the issue and may therefore allow for lower levels of underpricing. In addition, the expectation of (possibly price-inelastic) ECB demand for bonds in the secondary market may reduce uncertainty. Information-based explanations of underpricing therefore predict lower underpricing. On the other hand the bonds held by the ECB reduce the amount of tradable bonds and may therefore reduce secondary market liquidity. Further, the ECB may terminate the asset purchase programs and decide to sell its bond holdings, resulting in downward pressure on prices. This possibility may increase the liquidity risk. Liquidity-based explanations of underpricing thus predict that the asset purchase programs result in higher underpricing. We therefore formulate two competing hypotheses.

H7a: *The ECB's asset purchase programs lead to a reduction in corporate bond underpricing.*

H7b: *The ECB's asset purchase programs lead to an increase in corporate bond underpricing.*

4. Data and Methodology

4.1. Data

We collect data on 7,753 EUR-denominated bonds issued by financial and non-financial firms and by supranational institutions and agencies between January 03, 2002 and May 02, 2017.[5] The bonds in our sample, even though issued by different groups of issuers, have in common that they are all issued using the bookbuilding procedure described above. We

[5] Agencies are institutions which are backed by a government guarantee. Supranational institutions are backed by government guarantees from more than one government.

therefore expect their underpricing to depend on the same determinants. Still, however, there may be differences in the level of underpricing. We therefore repeat our analysis for subgroups of bonds and include issuer dummies in our regressions wherever appropriate. To include a bond in the sample we require a minimum issue volume of 250 million EUR, bullet repayment and a fixed coupon rate.

We source the data on corporate bonds from Bloomberg Professional and cross-check it with Thomson Reuters Datastream. We exclude 791 issues for which there were data inconsistencies.[6] We use data on daily bond prices from the same two sources, Bloomberg and Thomson Reuters Datastream. Both sources rely on data which is voluntarily reported by bond dealers.[7] Composite Bloomberg Bond Trader (CBBT) is a price calculated by Bloomberg which *"[...] strives to give an accurate indication of where you can reasonably expect to find opportunities to transact [...]"* (Bloomberg, 2017, p. 5).[8] It is based on the most recently updated executable quotes which do not necessarily represent the best available bid and ask quotes. The Datastream Composite Price (CMPM) is simply the mean of the quotes reported by dealers to Thomson Reuters Datastream with the highest and lowest bid and ask quotes excluded if more than three dealers contribute. CBBT data is available for 5,572 of the sample bonds and CMPM is available for 3,826 bonds,[9] with an intersection of 3,407 bonds. For 971 bonds no price data is available. 172 bonds are excluded because price data is incomplete or erroneous,[10] resulting in a sample of 5,819 bonds. Our main analysis is conducted using quote midpoints. In a robustness check reported in Section 5.6 we use bid quotes instead. We calculate bid-ask spreads from the CBBT and CMPM data to assess the liquidity of the sample bonds.

Since the two data sources differ with respect to the reporting dealers and with respect to details in the methodology, we expect slight deviations between the two sources. To check the reliability of the data we regress the CBBT quote midpoints on the CMPM quote midpoints. This regression yields an R-squared of 0.94 and a root mean squared

[6] Specifically, we identify bonds by their ISINs and compare 10 data fields (Coupon, Coupon Type, Coupon Frequency, Currency, Collateral Type, Amount Issued, Issue Price, Issue Date, First Coupon Date, Maturity Date). We exclude all bonds with inconsistencies in any of these fields.

[7] We rely on quote data because comprehensive trade data (such as the data provided by TRACE in the US) is unavailable for European bond markets.

[8] Other papers which use CBBT data include Schestag et al. (2016), Corradin and Rodriguez-Moreno (2014), Schuster (2014) and Schumacher et al. (2015).

[9] The number of bonds covered by CMPM is lower because CMPM data is only available from 2009 onward.

[10] We assume the reported prices to be erroneous if there is no price change during the first 40 trading days. We also eliminate bonds for which the reported issue price deviates from the issue price reported in Bloomberg or Datastream, respectively.

error of 0.53, i.e. 53 basis points (bps). Although the data from the two sources is not identical we consider it sufficiently similar to use data from both sources. When data from both sources is available we use the CBBT data with priority because it is based on current executable quotes.

4.2. Methodology

We measure underpricing by a bond's excess return over a value-weighted index during an event window extending from the issue day to the end of the event window.[11] In our main analysis we use a 40-day event window but we also report excess returns for shorter windows, ranging from one day to 30 days. While a one-day window is commonly used to measure underpricing of equity IPOs, corporate bonds trade less often (Cai et al., 2007; Goldberg and Ronn, 2013) and may therefore require a longer event window. In addition, the *pseudo-underwriter hypothesis* put forward by Goldberg and Ronn (2013) implies that a longer window might be appropriate in the case of bond markets. These authors argue that some large institutional investors acquire a larger position in a new issue than they intend to hold and subsequently redistribute these bonds to other investors. The results of Goldberg and Ronn (2013) suggest that the redistribution takes several weeks. Because there may be downward pressure on prices during the redistribution period we choose a 40-day event window.

With a 40-day event window we obviously need to adjust the bond returns. The results of Bessembinder et al. (2009) suggest that a value-weighted portfolio of matching bonds is better suited as an expected return proxy than an equally-weighted portfolio. We therefore use the market value-weighted Markit iBoxx EUR indices as benchmarks (Markit, 2010; Markit, 2012). These indices are based on quotes reported by bond dealers. They are available for different issuer types (financial firms, non-financial firms, agencies and supranationals), maturity bands (1-3 years, 3-5 years, 5-7 years, 7-10 years and 10+ years) and rating categories (AAA, AA, A, BBB and below). We match each bond in our sample with the corresponding index.[12]

[11] Alternatively, the underpricing can be calculated as the change in the bond's yield to maturity as in Goldberg and Ronn (2013). We report results based on abnormal yield changes as a robustness check in Section 5.6.

[12] Newly issued bonds sometimes have maturities which correspond almost exactly to the boundaries of the index ranges (i.e. 3, 5, 7 and 10 years). In these cases we intrapolate the index return from the two adjacent indices. There are also cases in which index values are missing (e.g. because an index was newly launched during our sample period) or an index contains less than 10 bonds. In these cases we use the appropriate parent index as benchmark. This step is necessary for 238 bonds, i.e. less than 5% of the sample.

Our underpricing measure corresponds to a 40-day event study cumulative abnormal return (CAR) with expected returns $E(R_{i,t})$ assumed to be equal to the total return of the corresponding iBoxx subindex $R_{m,t}$. The abnormal return $AR_{i,t}$ is defined as

$$AR_{i,t} = R_{i,t} - E(R_{i,t}) \tag{1}$$

where, following Bessembinder et al. (2009), $R_{i,t}$ is calculated as

$$R_i(t_1, t_2) = \frac{(P_{i,t_2} - P_{i,t_1}) + AI_{i,t_2}}{P_{i,t_1} + AI_{i,t_1}} \tag{2}$$

where the price $P_{i,t}$ is the CBBT or CMPM end-of-day mid-quote and $AI_{i,t}$ is the accrued interest at time t.

Our underpricing measure is the cumulative abnormal return $CAR_i(t_1, t_2)$,

$$CAR_i(t_1, t_2) = R_i(t_1, t_2) - R_m(t_1, t_2). \tag{3}$$

We average the CARs over the sample bonds to obtain the cumulative average abnormal return $CAAR(t_1, t_2)$,

$$CAAR(t_1, t_2) = \frac{1}{N} \sum_{i=1}^{N} CAR_i(t_1, t_2). \tag{4}$$

Some of the CARs in our sample are extremely large. This may be because of data errors or because of confounding events. In our main analysis we trim the sample at the 1% and 99% percentiles.[13] This reduces our sample to its final size of 5,703 bonds. In a robustness check we instead winsorize the sample at the 1% and 99% percentiles and obtain similar results. We test for significance of the CARs using a t-test and a non-parametric sign test.

To analyze the determinants of bond underpricing we estimate cross-sectional regressions. The dependent variable is the CAR. Our choice of independent variables is inspired by Cai et al. (2007) and Nagler and Ottonello (2017). We include several explanatory variables which proxy for the degree of uncertainty and the presence of informational asymmetries, namely issuer type dummies, dummies identifying covered bonds and subordinated bonds (senior unsecured bonds are the base category), the initial rating of the bond, the duration of the bond, the change in the 10 business days prior to the issue in the swap spread

[13] The corresponding CARs are -484 basis points and 634 basis points, respectively.

and in the corporate spread, and the Swaption Merril Lynch Option Volatility Index (SMOVE). The SMOVE can be interpreted as a forward-looking measure of swap rate volatility (Goldberg and Ronn, 2013). We further follow Cai et al. (2007) and include a dummy variable which indicates whether the bond was downgraded subsequent to the IPO plus a dummy variable indicating whether it was upgraded. In our regressions, we cluster standard errors at the issuer level, which is in line with Nagler and Ottonello (2017). To test hypothesis 4 on the bookbuilding procedure we include a dummy variable which indicates whether the bond issue under investigation is the first EUR-denominated bond of the issuer. Alternatively we include the time since the last issue by the same issuer. Some issuers (mostly investment banks) issue bonds and at the same time operate syndication desks. We include a dummy variable that identifies bonds issued by these dual-capacity institutions.

Available empirical evidence (e.g. Beatty and Ritter, 1986; Carter and Manaster, 1990) for equity IPOs and Datta et al. (1997) for bond IPOs) suggests that the reputation of the underwriter affects the underpricing of IPOs. Possible explanations for this relation are reputational concerns (e.g. Booth and Smith, 1986; Chemmanur and Fulghieri, 1994) and market power (Andres et al., 2014). To control for this effect we include a dummy variable (denoted Top3-Underwriter) which is set to 1 if at least one of the underwriters of an issue is among the top-3 underwriters in terms of issue volume during the previous 12 months. The information on underwriters is taken from SDC.

To test hypothesis 5 we include a bond's average bid-ask spread during the first 40 days of trading as a measure of secondary market illiquidity. We further include dummy variables for bonds issued during the crisis period (July 1, 2007 to March 31, 2009) and the post-crisis period. We analyze the impact on bond underpricing of the ECB's asset purchase programs using a difference-in-differences approach. For each program we include (a) a dummy which identifies bonds that satisfy the eligibility criteria for the program, (b) a dummy which is set to 1 during the period in which the program was active and (c) an interaction between these two dummies. For the PSPP and CSPP programs we further include dummy variables that identify bonds that have actually been purchased under the respective program. As additional control variables we include the treasury yield, the level of the swap spread, the level of the corporate spread and the number of bookrunners. Finally, we include country group (core EU, Nordic states, Euro crisis states

(Greece, Ireland, Italy, Portugal, Spain),[14] other EU, non-EU), weekday and month fixed effects.[15] Table 1 provides a detailed overview of the variables and their definitions.[16] Table A.2 in the appendix shows descriptive statistics.

[Insert Table 1 about here.]

5. Empirical Results

The presentation of the results is structured as follows. We first show that euro area bond issues are, on average, underpriced. We then discuss the results of our cross-sectional regressions aimed at identifying the determinants of underpricing. We continue by presenting evidence that underpricing has increased during the financial crisis and has remained at an elevated level since. In this subsection we also present our analysis of secondary bond market liquidity. Subsequently we present results of difference-in-differences analyses which show that the ECBs asset purchase programs have affected the level of underpricing. In the final subsection we describe the results of several robustness checks.

5.1. Corporate Bond Underpricing

Table 2 shows the CARs for various event windows for the full sample of 5,703 bonds issued between 2002 and 2017. The one-day abnormal return is 30.9 bps. It is positive in 66.9% of the cases, implying that more than two thirds of the bonds in our sample are underpriced. The underpricing increases with the length of the event window. The 40-day CAR (the longest window we consider) is positive for 65.3% of the bonds and amounts to 59.5 bps on average. It is thus almost twice as large as the one-day abnormal return. Both a t-test and a non-parametric sign test indicate that all CARs are significantly different from zero. These results, visualized in Figure 1, provide strong support for *hypothesis 1* and are also consistent with the pseudo-underwriter hypothesis of Goldberg and Ronn (2013).

[14] In additional model specifications (not reported) we have interacted a dummy for the Euro crisis countries with a crisis/post-crisis dummy. The coefficient on the interactio term is positive and significant while the other results are unchanged.

[15] We also ran a robustness check with industry fixed effects as suggested by Nagler and Ottonello (2017). The results are similar to those presented in the paper.

[16] The highest correlation between any pair of continuous variables is 0.42, implying that multicollinearity is not an issue.

[Insert Figure 1 about here.]

[Insert Table 2 about here.]

Table 3 shows the results of several sample splits. Panel A reports CARs for three event windows (0,1; 1,40 and 0,40) for subsamples sorted by issuer type. We find significant underpricing in each subsample and for each event window. Bonds issued by non-financial firms and subordinated bonds issued by financial institutions exhibit the largest underpricing (62 bps and 40 bps, respectively, over a one-day window and 112 bps and 94 bps over the full 40-day window). Covered and senior bonds issued by financial institutions, on the other hand, are much less underpriced (7 bps and 15 bps over a one-day horizon and 15 and 24 bps over a 40-day horizon). Figure 2 depicts the underpricing for bonds categorized by issuer type and collateral type.

[Insert Table 3 about here.]

[Insert Figure 2 about here.]

Panel B sorts the bonds according to their rating. There is a very pronounced and almost monotonic pattern, indicating that underpricing is larger for bonds with a lower rating.[17] This pattern is consistent with *hypothesis 2*. Panel C compares initial bond offerings (IBO, defined as cases in which an issuer issues a bond for the first time[18]) and seasoned bond offerings (SBO, cases in which an issuer has already issued bonds before). We find, in line with *hypothesis 4*, that IBOs are more underpriced than SBOs.

Panel D compares average underpricing in the pre-crisis period, the crisis period and the post-crisis period. It is lowest in the pre-crisis period. The one-day abnormal return is only 1 bp and is insignificant. Over the full 40-day window the abnormal return amounts to 9 bps. Underpricing increases strongly during the crisis. The one-day [40-day] abnormal

[17] The only exception are CCC-rated bonds which display lower average underpricing than B-rated bonds. However, the subsample of CCC-rated bonds contains only 25 observations. The result should thus be interpreted with care.

[18] For the construction of the IBO variable we use a larger sample consisting of 15,174 EUR-denominated bonds which includes fixed, floating, variable and zero coupon bonds. We classify an issue as an IBO if, within this large sample, we cannot identify an earlier EUR-denominated issue by the same issuer. Still, we cannot rule out that there have been prior issues by an issuer in other currencies. Please note that any bias introduced by this ambiguity works against finding differences between IBOs and SBOs.

return is 32 bps [98 bps]. The one-day abnormal return is even higher, at 37 bps, in the post-crisis period. The 40-day abnormal return in the post-crisis period amounts to 67 bps, more than seven times the value of the pre-crisis period. The time-series pattern is visualized in Figure 3. The figure shows average underpricing over a 40-day window for each quarter. It is apparent that the time-series variation in average underpricing is substantial. The highest underpricing is observed in the crisis years. The underpricing is slightly lower (and appears to be less volatile) in the post-crisis period. This time-series pattern is consistent with *hypothesis 5*. It is also consistent with the results of Nagler and Ottonello (2017) for the US corporate bond market. They found average underpricing of 23 bps pre-crisis, 72 bps in-crisis and 64 bps post-crisis.

In Panel E we compare the underpricing of bonds eligible to the ECB's asset purchase programs to the underpricing of non-eligible bonds. No clear pattern emerges. This finding should be interpreted with care, though, because eligible bonds are systematically different from non-eligible bonds. We will therefore now turn to a regression analysis in which we control for bond and market characteristics.

[Insert Figure 3 about here.]

5.2. Cross-Sectional Determinants of Underpricing

To analyze the determinants of underpricing we regress the 40-day CAR on bond and market characteristics. As outlined in Section 4.2 we include as bond characteristics issuer and bond type (with senior bonds issued by financial corporations being the base category and agencies and supranationals grouped together), rating, duration and the log of the issue size. Included market characteristics are the German treasury yield, the level and the 10-day change in the swap spread, the level and the 10-day change in the corporate spread, and the SMOVE as a measure of swap rate volatility. Detailed descriptions of all variables can be found in Table 1.

The results are shown in Table 4. They largely confirm those of the univariate analysis presented above and confirm *hypothesis 2*. Bonds issued by non-financial firms and subordinated bonds are significantly more underpriced than other bonds even after controlling for rating. The almost monotonic relation between rating and underpricing is also confirmed (again with the exception of the small subsample of CCC-rated bonds). The coefficient for the issue size is positive and significant. This implies that, after controlling for other bond

characteristics such as rating, larger issues are more underpriced, possibly because they are more difficult to place. The swap spread and the SMOVE are positively related to the level of underpricing while the relation between underpricing and the corporate spread is significantly negative.[19] We do not find any effect for the 10-day changes in the swap spread and the corporate spread.

The additional variables included in models 2, 3 and 4 are insignificant.[20] This implies that the level of underpricing is unaffected by the number of bookrunners, that the underpricing of bonds underwritten by the issuer is not different from the underpricing of other bonds, and that underwriter reputation is not related to the level of underpricing.[21] We do not include these variables in subsequent regression models.

[Insert Table 4 about here.]

5.3. Evidence on Economic Models of Underpricing

The results in the previous section suggest that, consistent with *hypothesis 2*, higher levels of bond risk and uncertainty about the bond value result in higher underpricing. In this section we augment our regression model by including additional explanatory variables which are related to specific theories of underpricing. The choice of variables is inspired by Cai et al. (2007). Some of the additional independent variables are only available for a subset of the bonds in our sample. Including all variables at once would grossly reduce the size of our sample, leaving us with only a small fraction of the initial sample size. We therefore decided to estimate several independent regression models.[22] The independent variables included in the previous regression (see Table 4) are included as control variables, but the coefficients are omitted to conserve space. The results are shown in Table 5.

The bookbuilding model by Benveniste and Spindt (1989) implies that underpricing should be lower for issuers that have gone through the bookbuilding process more recently.

[19] The negative relation between underpricing and the corporate spread, although consistent with the results of Goldberg and Ronn (2013) for the US market, is puzzling.

[20] As noted above, the number of observations is lower for models 2-4 because SDC does not provide the data on underwriter identity for all bonds in our sample.

[21] Inclusion of underwriter fixed effects (a robustness check proposed by Nagler and Ottonello (2017)) does not change our results. Because underwriter reputation may be time-varying, a fixed-effects specification may be inappropriate.

[22] Some of the additional independent variables (such as post-issue rating changes) are measured ex post. Limiting any bias resulting from this ex-post measurement is a second reason why we decided in favor of separate regression models.

We include a dummy variable named IBO (initial bond offering) that identifies cases in which the issue is the first issue by the respective issuer. For repeat issuers we include the time since the last issue.[23] The bookbuilding model predicts positive coefficients for both variables. Consistent with this prediction the coefficient on the IBO dummy in model 1 is positive and statistically significant. Its magnitude implies that initial bond offerings on average exhibit 25 bps higher underpricing than seasoned bond offerings. The coefficient for the time since the last bond issue is also significant. Its magnitude implies that, for every year passed, underpricing increases by 3.6 bps. Both results provide empirical support for the bookbuilding model of Benveniste and Spindt (1989) and *hypothesis 4*.

Signaling models predict that high-quality issuers choose underpricing in order to signal their quality. Rating downgrades subsequent to an issue should be less likely for high quality issuers. Consequently, signaling models predict that bonds which are downgraded after the issue are less underpriced. To test this hypothesis we include dummy variables which indicate whether a bond was downgraded or upgraded after the issue. The coefficient on the dummy variable that identifies bonds that have been downgraded after the issue is significantly *positive* while the coefficient on the upgrade dummy is insignificant. This result is at odds with signaling models of underpricing.

Liquidity-based explanations of underpricing predict that underpricing is a compensation for low secondary market liquidity. Besides the log of the issue size we include the average bid-ask spread during the first 40 days of secondary market trading as an additional explanatory variable. Larger bond issues should be more liquid while higher spreads indicate lower liquidity. Liquidity-based explanations of underpricing, summarized in *hypothesis 5*, thus predict a negative coefficient on issue size and a positive coefficient on the bid-ask spread. Our findings are in contrast to these predictions. The coefficient on the log of the issue size is positive, implying that larger bond issues are more underpriced. The coefficient on the bid-ask spread is insignificant.

In summary, our results do provide support for the bookbuilding theory of underpricing but are in contrast to the signaling models and to liquidity-based explanations of underpricing. Cai et al. (2007) for the US bond market and Ritter and Welch (2002) for the equity market arrive at similar conclusions.

[Insert Table 5 about here.]

[23] This variable is not defined for IBOs. Therefore, the number of observations is lower in model (2) than in model (1).

5.4. The Financial Crisis

To test whether the level of underpricing is higher during the financial crisis and in the post-crisis period, we follow Nagler and Ottonello (2017) and include two dummy variables which identify bonds issued during and after the crisis, respectively. We also include the control variables introduced in Section 5.2 in our regression modell.

The results are displayed in model 1 of Table 6. During the crisis underpricing increased by approximately 102 bps, an increase which is even larger than the increase documented in the univariate analysis in Section 5.1. This result provides strong support for *hypothesis 3*. The underpricing in the post-crisis period is lower than the underpricing during the crisis but is, in line with *hypothesis 6*, still 45 bps higher than the pre-crisis underpricing.

In model 2 we interact the in-crisis and post-crisis dummies with the issuer type dummies. The results imply that in-crisis the underpricing of bonds issued by financial and non-financial corporations increased by 110 and 144 bps, respectively. In contrast, bonds issued by Supranationals and Agencies (SSA) did not experience an increase in underpricing during the crisis. This finding is consistent with a flight to quality during the crisis because these issues are government-backed. The picture is similar during the post-crisis period. While the underpricing of bonds issued by financial and non-financial corporations is significantly higher than during the pre-crisis period, the difference, although positive, is insignificant for SSA-issued bonds. A potential reason for the latter finding is that SSA bonds, because of the government guarantees, require lower Basel III capital charges (see Bank for International Settlements, 2016).

In model 3 we interact the in-crisis and post-crisis dummies with dummies identifying bonds with above-median and below-median ratings. The results imply that lower-rated bonds experience a larger increase in underpricing both during and after the crisis.

[Insert Table 6 about here.]

Evidence for the US indicates that bid-ask spreads in the bond market increased during the crisis and remained at elevated levels after the crisis. The latter finding is ascribed to new regulation, in particular the Dodd Frank act and Basel III (Bessembinder et al., 2017; Dick-Nielsen and Rossi, 2016; Duffie, 2012). In models 4-6 of Table 6 we provide corresponding evidence for the euro area bond markets. We regress bid-ask spreads (measured over 40 days post-issuance) on the explanatory variables already included in

models 1-3. The results confirm the US evidence of a significant increase in bid-ask spreads. In fact, spreads appear to be even higher in the post-crisis period (+13.9 bps relative to the pre-crisis period) than in the in-crisis period (+4 bps). While during the crisis only spreads of bonds issued by financial corporations increase significantly, in the post-crisis period spreads of bonds issued by all issuer types are significantly higher than during the pre-crisis period. These findings are consistent with the hypothesis that Basel III and the regulations on proprietary trading (i.e. the Volcker Rule and the Liikanen Report) have contributed to a decrease in secondary market liquidity. We note, though, that our analysis does not allow for a causal interpretation of the findings.

5.5. The ECB's Asset Purchase Programs

As described in Section 2 we know for all five asset purchase programs which bonds were eligible. For the public sector purchase program and the corporate sector purchase program we additionally know which bonds were actually bought. Purchases under the PSPP can only be made in the secondary market. Under the CSPP the ECB is authorized to purchase bonds in the primary and secondary markets. While we know whether a specific bond was purchased, we do not know whether it was purchased in the primary or in the secondary market.[24]

Our analysis of the impact on bond underpricing of the asset purchase programs proceeds in three steps. In the first step (specifications (1) and (2) below) we focus on the PSPP and CSPP and make use of the information on which bonds were purchased. In the second step (specification (3)) we consider all five programs but only use the information on whether a bond was eligible for one of the programs. In the final step (specification (4)) we use all available information. Specifically, we differentiate between eligible and non-eligible bonds for the three covered bond purchase programs, and we differentiate between eligible and bought bonds, eligible and non-bought bonds, and non-eligible bonds for the PSPP and CSPP.

We use the same regression framework as before. The dependent variable is the 40-day CAR, and we include the same set of control variables as before. Our first specification includes a dummy variable (denoted *ECB eligible & purchased*) which is set to 1 if a bond satisfies the eligibility criteria of the PSPP or CSPP, has been issued while the

[24] We also do not know *when* the purchase was made. There may thus be cases in which the ECB bought a bond in the secondary market after the end of our 40-day event window. Including these cases in our analysis biases the results against finding an effect on underpricing of the PSPP and CSPP.

respective program was active, and has been purchased by the ECB. The results are shown in the first column of Table 7. The coefficient on the *ECB eligible & purchased* dummy implies that, consistent with *hypothesis 7a*, underpricing was significantly lower (by 41 bps) for bonds purchases under the PSPP or CSPP. We next differentiate between the two programs. We include two dummy variables identifying bonds that were purchased under either the PSPP or the CSPP. The results are shown in the second column of Table 7. Bonds purchased under the CSPP are significantly (by 45 bps) less underpriced. The coefficient for bonds purchased under the PSPP is negative but insignificant. This may be because the PSPP does not allow for primary market purchases.

Our third specification only uses the information on whether a bond was eligible for one of the programs (but ignores the information whether the bond was actually purchased under the PSPP or CSPP). We use a difference-in-differences approach and include, for each of the five programs, three dummy variables. The first identifies bonds that satisfy the eligibility criteria for the program (the "treatment dummy"),[25] the second identifies bonds issued while the program was active (the "post dummy"), and the third is the interaction of the two. The coefficient on the interaction term indicates whether eligible bonds issued while the program was active exhibit a level of underpricing different from that of the controls. The results are displayed in the third column of Table 7. The interaction terms for three of the programs, the CBPP1, CBPP2 and PSPP, are insignificant. The insignificant result for the PSPP confirms our earlier finding and may, again, be due to the fact that the program does not allow primary market purchases. The CBPP1 and CBPP2 were small programs in terms of the number of eligible bonds (116 and 72, respectively, as compared to 281 and 177 for the CBPP and CSPP). Also, both programs were active for less than one year. It may thus not be too surprising that we do not find a significant effect. The coefficients for the CBPP3 and the CSPP are significantly negative. They indicate that eligible bonds issued while the program was active exhibited lower underpricing. The effect is also economically significant, at 20.6 bps and 27.2 bps for the CBPP3 and the CSPP, respectively.

The fourth specification extends the difference-in-differences framework by differentiating, for the PSPP and the CSPP, between those eligible bonds that were and that were not bought by the ECB (see column 4 in Table 7). The results for the PSPP are, as before,

[25] Note that the eligibility criteria for CBPP2 and CBPP3 are identical. We therefore only include one treatment dummy for both programs. The differences, outlined in Section 2, between the criteria of the CBPP2 and CBPP 3 only have implications for when and how many bonds the ECB may buy, but not for *which* bonds the ECB may buy.

insignificant. The results for the CSPP indicate that it is the eligibility for the program that matters, not whether the ECB actually purchased a bond. In fact, the coefficient for those bonds that were not purchased is numerically larger (at 32.7 bps) than the coefficient for the bonds that were purchased.[26]

[Insert Table 7 about here.]

In summary, the results provide some support for our *hypothesis 7a*. Bonds which are eligible for purchase by the ECB appear to exhibit lower underpricing. The alternative *hypothesis 7b*, stating that the asset purchase programs result in an *increase* in underpricing, is rejected by our results. This hypothesis is based on the assumption that the ECB's asset purchase programs decrease secondary market liquidity. Our data allows to test whether this is indeed the case. We repeat the previous analysis with the average bid-ask spread during the 40 days after the issue as dependent variable. The results are shown in Table 8. The coefficients on the in-crisis and post-crisis dummies are positive and significant and thus confirm our earlier finding that liquidity has decreased during and after the financial crisis. Model specifications (1) and (2) imply that bonds that were bought by the ECB under the PSPP or CSPP have *lower* spreads. In specifications (3) and (4) the results for all programs except the CBPP1 indicate that the spreads of eligible bonds are equal to or smaller than those of the controls. These results clearly do not support the hypothesis that the asset purchase programs have led to a decrease in secondary market liquidity. Thus, the assumption on which hypothesis 7b is based cannot be confirmed.

[Insert Table 8 about here.]

5.6. Robustness Checks

As noted in the introduction, there are two approaches to measure underpricing of bonds, abnormal returns as used in the preceeding sections, and abnormal yield changes as used by e.g. Hale and Santos (2006) and Goldberg and Ronn (2013). The abnormal yield change, $AYC_{i,t}$, is defined as the difference between the actual yield change, $YC_{i,t}$, and the expected yield change, $E(YC_{i,t})$. The latter is estimated by the yield change of the corresponding iBoxx subindex.

[26] In spite of its magnitude the coefficient is not significant, most likely because there were only 35 (out of a total of 177) eligible bonds that were not purchased by the ECB.

$$AYC_{i,t} = YC_{i,t} - E(YC_{i,t}) \tag{5}$$

The yield change is simply the change in the yield to maturity of the bond and the index, respectively.

$$YC_{i,t} = YTM_{i,t} - YTM_{i,t-1} \tag{6}$$

The underpricing is then defined as the sum of the abnormal yield changes, multiplied by (-1) in order to obtain a positive value when the bond issue is underpriced.

$$CAYC_i(t_1, t_2) = -\sum_{t=t_1}^{t_2} AYC_{i,t} \tag{7}$$

The results are shown in Figure 4. 68.9% of the bonds in our sample are underpriced. The average underpricing over a 40-day window is 10 bps. Slightly more than half of the underpricing (5.3 bps) accrues on the first day while the CAAYC over days 1 to 40 is 4.7 bps. Yield changes and returns are (under the assumptions of the duration concept) related by

$$YC_i = -\frac{(1 + YTM_i)R_i}{D_i} \tag{8}$$

where YTM and YC are yield and yield change, respectively, R is the return and D denotes duration. Consequently, abnormal yield changes are much smaller in magnitude than abnormal returns.

[Insert Figure 4 about here.]

Comparing Figure 4 to Figure 3 reveals that the time-series patterns of abnormal yield changes and abnormal returns are similar. The cumulative abnormal yield change amounts to 3.0 bps in the pre-crisis period, 19.7 bps during the crisis and 10.7 bps in the post-crisis period. It appears, however, that the dispersion of the abnormal yield changes is lower. Figure 5 shows abnormal yield changes by issuer type. Similar to what we find for abnormal returns, the abnormal yield changes are largest for bonds issued by non-financial firms (19.1 bps on average), followed by subordinated bonds issued by financial institutions (12.2 bps). Covered bonds and senior bonds issued by financial institutions are the least

underpriced (4.4 bps and 2.4 bps, respectively). Table A.3 and Table A.5 in the appendix show cumulative abnormal yield changes for subsamples and regression results. They are qualitatively similar to the results that we obtain for abnormal returns. The coefficient values are smaller because, as outlined above, abnormal yield changes are much smaller than abnormal returns.

[Insert Figure 5 about here.]

Our analysis so far has been based on quote midpoints.[27] However, investors cannot trade at midpoints. Therefore we repeat the analysis using secondary market bid prices instead. This will necessarily decrease the underpricing by the half spread. Table A.4 in the appendix shows the results. The underpricing over the full 40-day window amounts to 40.9 bps and is highly significant. The underpricing on the first day of secondary market trading is 16.1 bps and is also significant. The table also shows the results for various sample splits. They are largely consistent with those obtained using quote midpoints. However, bonds issued pre-crisis, covered bonds and AAA-rated bonds do not exhibit significant underpricing when bid quotes are used. Columns 1 and 2 in Table A.5 in the appendix show the regression results that we obtain when using bid quotes and quote midpoints, respectively.[28] The results are very similar to each other. We therefore conclude that using bid quotes instead of quote midpoints does not significantly alter our results.

6. Conclusion

Underpricing is a well-documented phenomenon in equity markets as well as in the US corporate bond market. Much less is known about the euro area corporate bond market. In this paper we attempt to fill this gap. We perform the most comprehensive study of underpricing in the euro area bond market so far. Our sample consists of 5,703 EUR-denominated corporate bonds from different issuer types (Financials, Non-Financials, SSAs) and with different collateral types (Covered, Senior Unsecured, Subordinated). The average underpricing during a 40-day event window amounts to 59 bps. We document positive and statistically significant underpricing for various subsamples. A regression analysis reveals that the level of underpricing is related to variables proxying for the risk of

[27] Remember that reliable data on transaction prices (such as the data provided by TRACE in the US) is not available for European bonds.
[28] Model (1) in the table is identical to model (6) in Table 7.

the bond, the uncertainty about the value of the bond and the existence of informational asymmetries. Specifically we find that underpricing is related to the initial rating of a bond, to the swap spread, to the corporate spread and to the swap spread volatility. Our results provide support for the bookbuilding model of Benveniste and Spindt (1989) which states that underpricing is a compensation for information revealed during the bookbuilding process. We do not find support for signaling models of underpricing or for liquidity-based explanations of underpricing.

Underpricing in the euro area bond market increased dramatically during the financial crisis and remained at an elevated level ever since. We also document that the liquidity of the secondary market for EUR-denominated bonds has declined considerably. These results are consistent with the US evidence (Nagler and Ottonello, 2017; Bao et al., 2017; Bessembinder et al., 2017; Dick-Nielsen and Rossi, 2016) and may represent unintended side effects of new regulation enacted after the financial crisis.

Analyzing the European Central Bank's asset purchase programs, we find evidence that the programs have resulted in reduced underpricing. This is particularly true for bonds eligible for the corporate sector purchase program (CSPP).

Our results are important for issuers because underpricing affects their cost of borrowing. They are further important for regulators because they suggest that the post-crisis changes in banking regulation may have negative implications for secondary market liquidity. Finally, they contribute to a better understanding of the implications of the ECB's unconventional monetary policy for bond markets.

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Figures and Tables

Figure 1: Cumulative Average Abnormal Return. We plot the Cumulative Average Abnormal Return computed according to Equation 4 from $CAAR(0,0)$ to $CAAR(0,40)$ for the complete sample of 5,703 bonds. For each $CAAR(t_1,t_2)$, we also calculate the 99% confidence interval and plot the upper and lower bound.

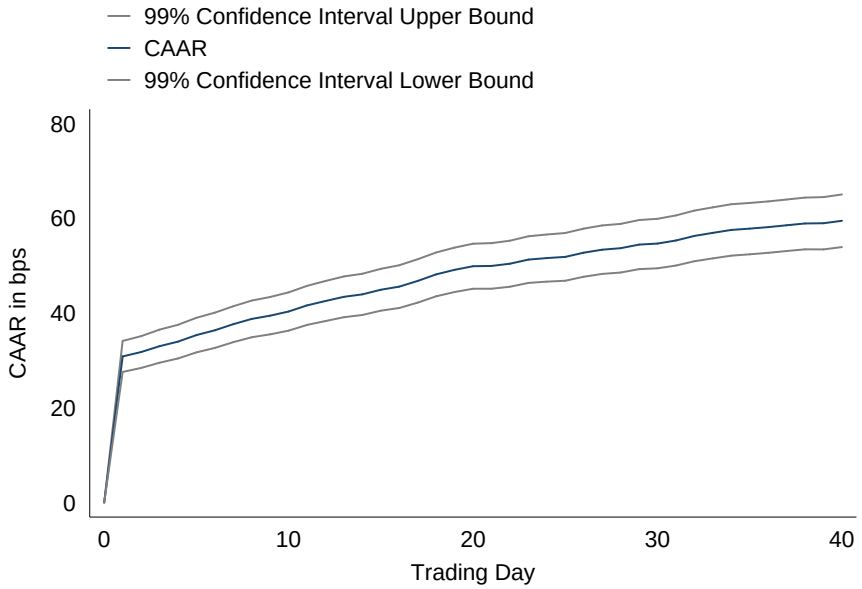

Figure 2: CAAR by Issuer Type and Collateral Type. We plot the Cumulative Average Abnormal Return computed according to Equation 4 from $CAAR(0,0)$ to $CAAR(0,40)$ for six subsamples divided by issuer type (Financial, Non-Financial, Agency, Supranational) and collateral type (Covered, Senior Unsecured, Subordinated).

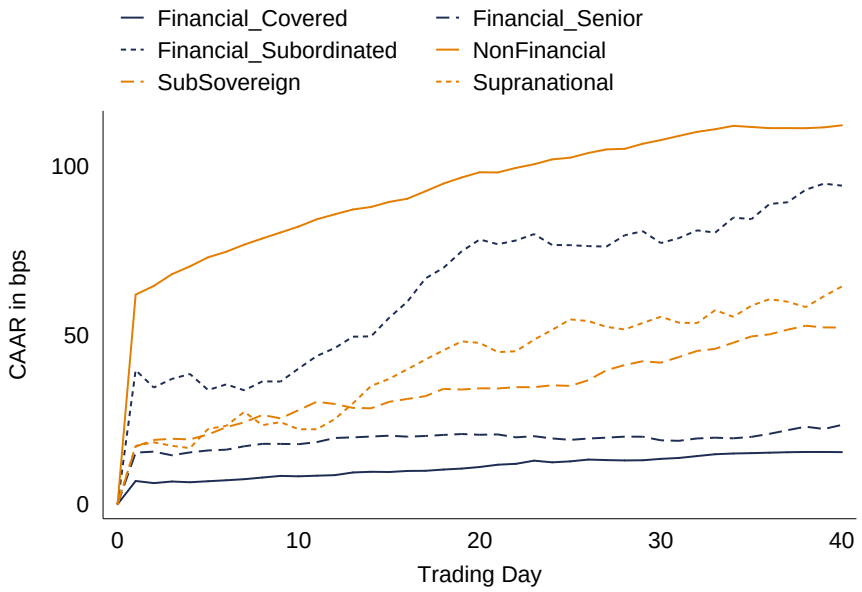

Figure 3: Quarterly CAAR(0,40). We plot the $CAAR(0,40)$ according to Equation 4 for the time period from Q1/2002 until Q2/2017. As a comparison, we also plot the 12-Month Moving Average $CAAR(0,40)$ (y-axis #1) and the 12-Month Moving Average Bid-Ask-Spread (y-axis #2) from the sample.

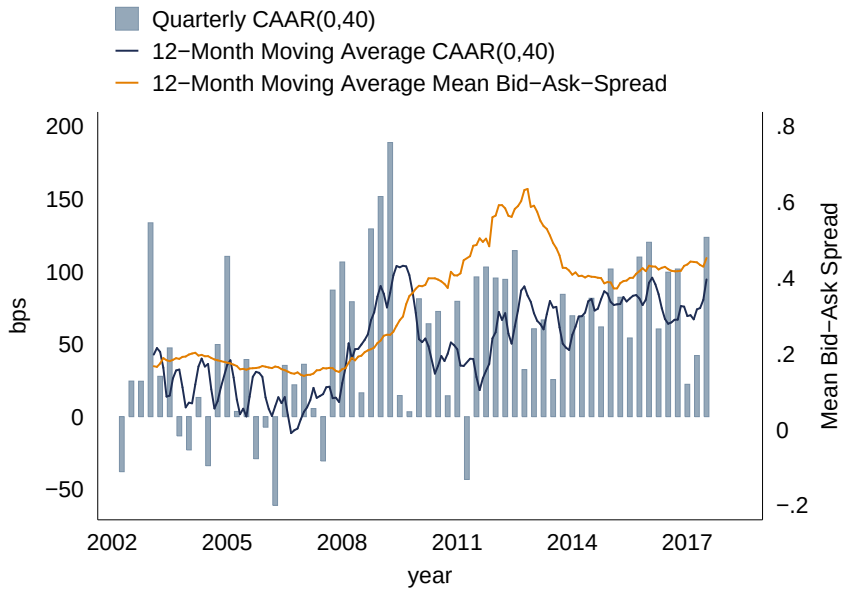

Figure 4: Quarterly CAAYC(0,40). We plot the $CAAYC(0, 40)$ computed as the (negative) mean of the $CAYC_i(0, 40)$ according to Equation 7 for the time period from Q1/2002 until Q2/2017. As a comparison, we also plot the 12-Month Moving Average $CAAYC(0, 40)$ (y-axis #1) and the 12-Month Moving Average Bid-Ask-Spread (y-axis #2) from the sample.

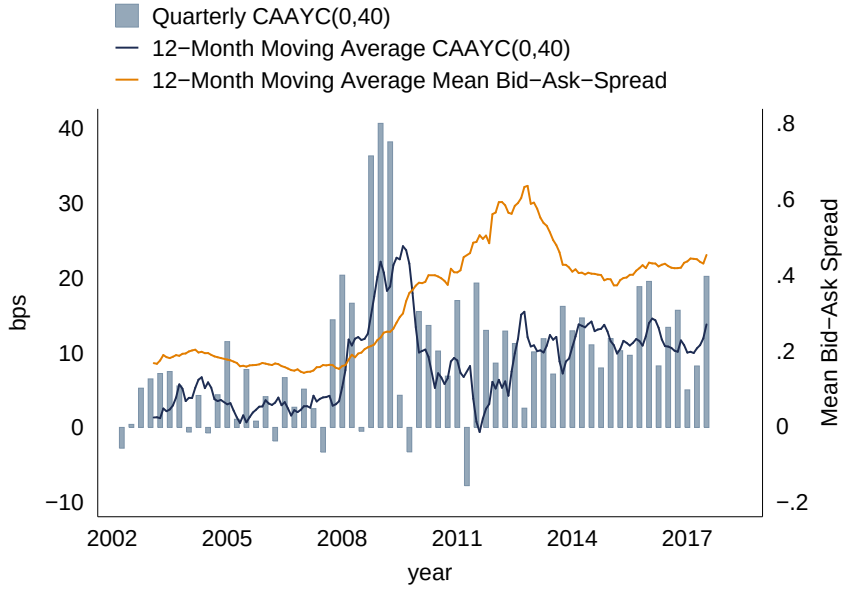

Figure 5: CAAYC by Issuer Type and Collateral Type. We plot the Cumulative Average Abnormal Yield Change computed as the mean of the $CAYC_i(0, 40)$ from Equation 7 for six subsamples divided by issuer type (Financial, Non-Financial, Agency, Supranational) and collateral type (Covered, Senior Unsecured, Subordinated).

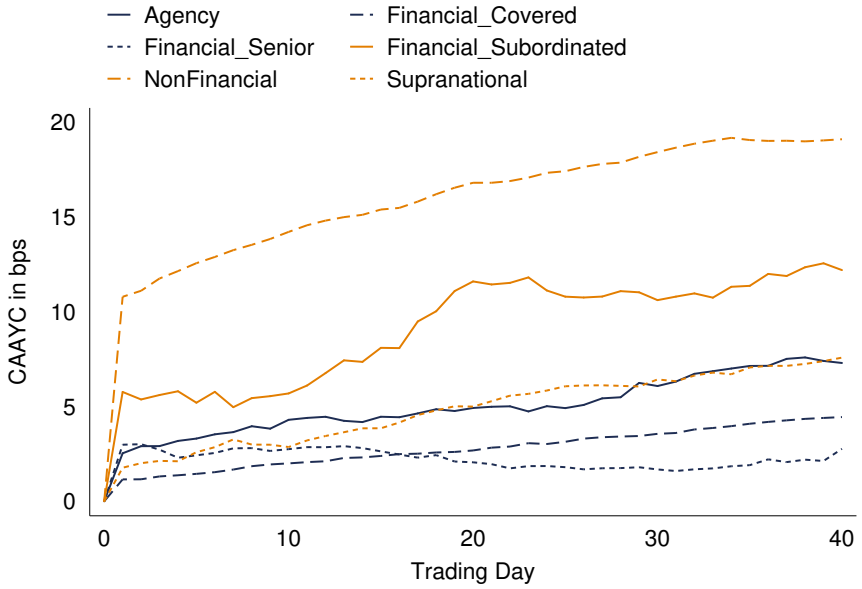

Table 1: Explanatory Variables This table lists and describes the specific explanatory variables used in the cross-sectional regressions. The respective data source is also listed.

Variable	Description	Source(s)
Issuer Type (Financial / Non-Financial / SSA)	The issuer type is controlled for through dummy variables. The sample includes three issuer types: Financials, Non-Financials and SSAs. (We group Agencies and Supranationals together as SSAs.)	Bloomberg
Collateral Type (Covered / Senior / Subordinated)	The sample includes three different collateral types, i.e. covered bonds, senior unsecured bonds and subordinated bonds. We identify them using dummy variables.	Bloomberg
Rating (AAA / AA / A / BBB / BB / B / CCC)	As bond ratings are issued by different rating agencies and may deviate from each other, the lowest available rating of the three available rating agencies (S&P, Moody's, Fitch) is used and dummy variables are created for every rating category.	Bloomberg
Duration (in years)	The duration is the present-value-weighted average maturity time of the bond payoffs.	Bloomberg, Own Calculation
# of bookrunners	The # of bookrunners per issue is documented in SDC Platinum.	SDC Platinum
Own Underwriter (0/1)	Issuers who themselves operate syndication desks (i.e. mostly investment banks) may act as underwriters for their own issues. The dummy variable is obtained manually from matching bookrunners to bond issuers.	SDC Platinum, Own Calculation
Top3-Underwriter (0/1)	Indicates whether at least one of the underwriters of a bond is among the three underwriters with the highest market share as measured by the underwritten issued amount in the past 12 months.	SDC Platinum, Own Calculation
Treasury Yield	The treasury yield is linearly interpolated between coupon-paying German government bonds.	Datastream

Continued on next page

Table 1 – continued from previous page

Variable	Description	Source(s)
Swap Spread	The spread between the fixed-rate leg of liquid swap contracts and the yield on German government bonds, a measure of the risk premium implied in swap contracts.	Datastream, Own Calculation
Corporate Spread	The spread between yields on corporate bonds and the treasury rate. To measure this risk premium, the yield of the broadest iBoxx corporate bond index (average maturity $\approx$ 5 years) is compared to the 5-year treasury rate.	Datastream, Own Calculation
10-day Δ in the Swap Spread	As shown by Goldberg and Ronn (2013) recent changes in risk premia may also affect underpricing.	Datastream, Own Calculation
10-day Δ in the Corporate Spread	Similar to the 10-day delta in the swap spread, a 10-day delta in corporate spreads can be calculated.	Datastream, Own Calculation
EUR Swaption Merill Lynch Options Volatility Estimate (SMOVE)	The EUR Swaption Merill Lynch Options Volatility Estimate (SMOVE) can be interpreted as a forward-looking measure of swap rate volatility.	Bloomberg
Time since last bond issue (in years)	The time is calculated on the basis of a larger dataset containing 12,061 bonds, which includes floating rate notes and bonds issued before 1/1/2002. Obviously these bonds required a book-building process as well, so that they should be taken into account for calculating the time since the last bond issue of a firm.	Bloomberg, Datastream
IBO (0/1)	Given the available dataset, a bond is defined as an IBO if it is the first EUR-denominated bond issue of that firm.	Bloomberg, Datastream
Rating Changes	From Datastream, the current rating can be compared with the initial rating to arrive at the number of notches a bond has been upgraded (+) or downgraded (-) since issuance.	Bloomberg, Datastream

Continued on next page

Table 1 – continued from previous page

Variable	Description	Source(s)
Upgrade/Downgrade Dummies	Similar to the *Rating Changes*, we construct dummies for whether a bond was upgraded/downgraded subsequent to issuance, a variable inspired by Cai et al. (2007)	Bloomberg, Datastream
Amount Issued (in million EUR)	Cai et al. (2007) show that the amount issued is a good proxy of liquidity as it is related to both trading volume and bid-ask-spreads.	Bloomberg, Datastream
Bid-Ask Spread	The mean CBBT bid-ask-spread during the first 40 trading days as a measure of liquidity.	Bloomberg
Pre-Crisis, In-Crisis, Post-Crisis (0/1)	Following Nagler and Ottonello (2017), possible structural changes in underpricing are accounted for with dummy variables for these periods. The crisis period is approximated as from 7/1/2007 until 3/31/2009.	Own Calculation
Asset purchase programs (diff-in-diff estimators)	For each of the five asset purchase programs relevant for the sample, a diff-in-diff estimation is applied with the setup of a before/after dummy and a treatment/control dummy.	ECB, Own Calculation

[28] Trading volume is generally not available as there is no requirement for public dissemination of trades. Bid-Ask-Spreads may be obtained from market data providers such as Bloomberg or Datastream, but apparently these are derived only from unsolicited contributions of dealers. As such, they are not always available and even if they are available for a particular bond, they may not always be an accurate measure.

Table 2: Cumulative Abnormal Returns. This table displays the number of observations (N), the mean, the standard error (SE), the 99% confidence interval, the t-statistic, the percentage of positive $CAR(t_1, t_2)$ and the p-value from the non-parametric sign test (Snedecor and Cochran, 1989) for $CAR(0, 1)$ up to $CAR(0, 40)$ across the complete sample.

$CAR(t_1, t_2)$	**N**	**Mean**	**SE**	**99% Confidence Interval**	**t-stat**	**% positive** $CAR(t_1, t_2)$	**p-value (signtest)**
CAR(0,1)	5703	30.89	1.27	[27.62; 34.16]	24.37	66.93%	0.0000
CAR(0,2)	5703	31.80	1.30	[28.46; 35.15]	24.47	66.23%	0.0000
CAR(0,3)	5703	33.05	1.36	[29.55; 36.54]	24.39	66.11%	0.0000
CAR(0,4)	5703	34.01	1.38	[30.46; 37.56]	24.69	66.18%	0.0000
CAR(0,5)	5703	35.38	1.41	[31.74; 39.03]	25.01	66.18%	0.0000
CAR(0,10)	5703	40.35	1.57	[36.32; 44.39]	25.77	66.51%	0.0000
CAR(0,20)	5703	49.91	1.84	[45.16; 54.66]	27.08	66.54%	0.0000
CAR(0,30)	5703	54.68	2.03	[49.46; 59.9]	26.99	65.91%	0.0000
CAR(0,40)	5703	59.48	2.15	[53.93; 65.02]	27.63	65.28%	0.0000

Table 3: Underpricing for Sub-Samples. This table displays the number of observations (N), mean and t-statistic for $CAAR(0,1)$, $CAAR(1,40)$ and $CAAR(0,40)$ for different subsamples.

		CAAR(0,1)		CAAR(1,40)		CAAR(0,40)	
	N	Mean	t-stat	Mean	t-stat	Mean	t-stat
Complete Sample	5,703	30.89***	(24.37)	28.59***	(16.66)	59.47***	(27.63)
Panel A: By Issuer Type							
Financial (Covered)	1573	6.912***	(4.29)	8.456***	(3.76)	15.37***	(5.39)
Financial (Senior)	1156	15.32***	(5.47)	8.230**	(2.06)	23.55***	(5.08)
Financial (Subord.)	140	39.64***	(3.05)	54.53***	(3.12)	94.17***	(4.56)
Sub-Sovereign	576	17.05***	(5.01)	35.19***	(6.33)	52.24***	(8.01)
Supranational	176	17.27***	(2.81)	47.10***	(4.78)	64.38***	(5.37)
Non-Financial	2082	62.04***	(26.52)	49.96***	(16.32)	112.0***	(29.01)
Panel B: By Rating							
AAA	1565	4.883***	(2.99)	11.85***	(4.95)	16.73***	(5.61)
AA	779	18.38***	(6.24)	28.85***	(6.87)	47.22***	(9.19)
A	1430	33.19***	(13.46)	20.24***	(6.11)	53.43***	(12.85)
BBB	1278	47.48***	(17.91)	34.88***	(9.23)	82.36***	(17.82)
BB	282	78.52***	(10.64)	68.97***	(7.00)	147.5***	(12.11)
B	135	115.6***	(9.00)	139.5***	(7.96)	255.1***	(13.12)
CCC	25	55.11*	(2.00)	105.3*	(1.75)	160.5***	(2.96)
NA	208	32.90***	(2.87)	37.37***	(2.93)	70.27***	(4.39)
Panel C: By IBO/SBO							
IBO	850	65.65***	(16.96)	52.89***	(10.86)	118.5***	(18.46)
SBO	4853	24.80***	(18.97)	24.33***	(13.36)	49.13***	(22.00)
Panel D: By Time Period							
Pre-Crisis	878	1.130	(0.42)	7.925***	(2.64)	9.055**	(2.15)
In-Crisis	307	31.73***	(5.63)	66.50***	(9.08)	98.23***	(10.40)
Post-Crisis	4518	36.62***	(25.31)	30.03***	(14.89)	66.64***	(26.86)
Panel E: By Asset Purchase Program Eligibility							
CBPP1	116	16.83***	(4.62)	17.85*	(1.84)	34.67***	(3.29)
CBPP2	72	38.68***	(3.88)	5.451	(0.32)	44.13**	(2.07)
CBPP3	281	12.63***	(3.45)	13.57***	(3.58)	26.20***	(4.90)
PSPP	65	21.72**	(2.25)	29.63**	(2.01)	51.35***	(2.84)
CSPP	177	34.75***	(5.11)	38.48***	(5.73)	73.23***	(7.67)
None	4992	32.11***	(23.00)	29.65***	(15.64)	61.76***	(26.06)

t-statistics in parentheses

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

Table 4: Determinants of Underpricing: Cross-Sectional Regressions. This table displays the coefficients and the t-statistics for cross-sectional regressions of $CAR_i(0, 40)$ on the control variables described in Table 1.

	(1) CAR(0,40)	(2) CAR(0,40)	(3) CAR(0,40)	(4) CAR(0,40)
Non-Financial Issuer	56.36***	42.34***	45.52***	42.97***
	(6.57)	(3.96)	(4.42)	(4.01)
SSA Issuer	19.27*	11.53	11.22	12.08
	(1.75)	(0.90)	(0.88)	(0.94)
Covered Bond	9.30	-0.43	2.47	-0.02
	(1.01)	(-0.04)	(0.23)	(-0.00)
Subordinated Bond	68.46**	58.27**	58.62**	58.43**
	(2.43)	(2.27)	(2.28)	(2.28)
NA	55.22***	83.15***	80.47***	83.41***
	(2.81)	(2.84)	(2.75)	(2.85)
AA	26.51***	27.05***	26.56***	27.03***
	(3.97)	(3.70)	(3.60)	(3.69)
A	30.58***	39.91***	39.18***	39.96***
	(3.09)	(3.27)	(3.20)	(3.27)
BBB	48.23***	53.79***	53.12***	53.73***
	(4.19)	(3.65)	(3.61)	(3.65)
BB	112.32***	73.88***	74.32***	73.45***
	(6.33)	(3.50)	(3.53)	(3.47)
B	214.71***	199.92***	199.42***	199.71***
	(7.55)	(4.94)	(4.92)	(4.88)
CCC	127.54	-51.45	-49.10	-50.32
	(1.51)	(-0.50)	(-0.48)	(-0.49)
Duration	0.03	-2.32	-2.19	-2.36
	(0.02)	(-1.10)	(-1.03)	(-1.11)
ln(Amount Issued)	15.86***	14.76***	15.36***	15.01***
	(3.06)	(3.31)	(3.42)	(3.37)
German Treasury Yield	-91.80**	-69.87	-82.27*	-68.67
	(-2.34)	(-1.40)	(-1.69)	(-1.38)
Swap Spread	1127.71***	1641.28***	1641.95***	1640.62***
	(2.92)	(3.60)	(3.58)	(3.60)
10-day Δ Swap Spread	1806.11*	1241.69	1253.45	1239.32
	(1.69)	(1.04)	(1.05)	(1.04)
Corporate Spread	-147.96**	-182.71***	-181.57***	-181.27***
	(-2.47)	(-2.61)	(-2.60)	(-2.59)
10-day Δ Corporate Spread	195.29	103.86	87.79	102.15
	(0.36)	(0.17)	(0.14)	(0.17)
SMOVE	89.10***	110.35***	112.39***	110.31***
	(3.16)	(3.33)	(3.38)	(3.33)
Own Underwriter		4.25		4.16
		(0.60)		(0.59)
Nr. of Bookrunners		2.17		2.59
		(1.26)		(1.42)
Top3-Underwriter			-0.85	-4.10
			(-0.16)	(-0.74)
Observations	5,545	3,471	3,471	3,471
Adjusted R-squared	0.118	0.082	0.081	0.082
Clustered SE	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes

t-statistics in parentheses
* p<0.1 ** p<0.05 *** p<0.01

Table 5: Cross-Sectional Regression to test Economic Models of Underpricing. This table displays the coefficients and the t-statistics for the cross-sectional regressions regarding the economic models of underpricing. Model (1) and (2) test the bookbuilding model of Benveniste and Spindt (1989). Model (3) tests signaling models. Model (4) tests liquidity-based explanations of underpricing.

	(1) CAR(0,40)	(2) CAR(0,40)	(3) CAR(0,40)	(4) CAR(0,40)
ln(Amount Issued)	17.42***	18.62***	18.10***	16.30***
	(3.41)	(3.31)	(3.38)	(3.55)
IBO	25.08***		26.73***	23.42***
	(3.11)		(3.32)	(2.96)
Time since last bond issue		3.62**		
		(2.03)		
Bond Upgraded			5.57	
			(0.77)	
Bond Downgraded			19.67**	
			(2.46)	
Bid-Ask-Spread				0.20
				(1.53)
Observations	5,545	4,533	5,545	5,424
Adjusted R-squared	0.120	0.087	0.122	0.122
Control Variables X_i	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes

t-statistics in parentheses
* p<0.1 ** p<0.05 *** p<0.01

Table 6: Cross-Sectional Regression to test for a Post-Crisis Structural Change. This table displays the coefficients and the t-statistics for the cross-sectional regressions regarding the post-crisis structural change. Model (1), (2) and (3) use underpricing defined as $CAR_i(0,40)$ as the dependent variable. Model (4), (5) and (6) use bid-ask-spreads as the dependent variable. In models (2) and (5) interaction terms with the issuer type are applied instead of simple time period dummies. In models (3) and (6) interaction terms with a newly constructed dummy for an initial above- or below-median-rating are applied.

	(1) CAR (0,40)	(2) CAR (0,40)	(3) CAR (0,40)	(4) Bid-Ask-Spread	(5) Bid-Ask-Spread	(6) Bid-Ask-Spread
In-Crisis	102.43***			3.80*		
	(8.25)			(1.81)		
Post-Crisis	45.09***			13.95***		
	(4.47)			(6.82)		
In-Crisis × Non-Financial		144.26***			1.84	
		(6.20)			(0.49)	
In-Crisis × Financial		110.20***			6.39***	
		(7.18)			(2.78)	
In-Crisis × SSA		2.87			-1.25	
		(0.15)			(-0.52)	
Post-Crisis × Non-Financial		66.37***			14.14***	
		(4.86)			(5.53)	
Post-Crisis × Financial		39.33***			13.56***	
		(3.72)			(6.26)	
Post-Crisis × SSA		23.41			13.64***	
		(1.33)			(4.11)	
In-Crisis × Above-Median-Rating			67.46***			5.55**
			(5.03)			(2.25)
In-Crisis × Below-Median-Rating			153.34***			-0.75
			(6.94)			(-0.29)
Post-Crisis × Above-Median-Rating			38.23***			12.40***
			(3.66)			(5.80)
Post-Crisis × Below-Median-Rating			49.29***			13.53***
			(4.09)			(5.51)
Observations	5,545	5,545	5,545	5,424	5,424	5,424
Adjusted R-squared	0.132	0.135	0.134	0.278	0.277	0.277
Control Variables X_i	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes

t-statistics in parentheses
* p<0.1 ** p<0.05 *** p<0.01

Table 7: Cross-Sectional Regression to test for an APP Structural Change in Underpricing. This table displays the coefficients and the t-statistics for the cross-sectional regressions regarding the asset purchase programs.

	(1) CAR(0,40)	(2) CAR(0,40)	(3) CAR(0,40)	(4) CAR(0,40)
In-Crisis	100.68***	101.09***	103.95***	104.11***
	(8.10)	(8.14)	(8.13)	(8.14)
Post-Crisis	42.68***	43.22***	30.73***	31.04***
	(4.20)	(4.26)	(2.73)	(2.75)
ECB eligible & purchase	-41.20***			
	(-3.67)			
CBPP1 period			18.13	17.93
			(1.41)	(1.40)
CBPP1 eligible			-29.13**	-29.03**
			(-2.44)	(-2.43)
CBPP1 period × eligible			22.28	22.34
			(1.32)	(1.32)
CBPP2 period			38.68***	38.81***
			(3.00)	(3.01)
CBPP2/3 eligible			35.95***	35.84***
			(3.25)	(3.24)
CBPP2 period × eligible			-1.59	-1.56
			(-0.07)	(-0.07)
CBPP3 period			18.92	18.99
			(1.49)	(1.50)
CBPP3 period × eligible			-20.59**	-20.47**
			(-2.18)	(-2.17)
PSPP period			-9.67	-9.62
			(-0.84)	(-0.83)
PSPP eligible			-14.42	-14.49
			(-1.16)	(-1.17)
PSPP period × eligible			-5.71	
			(-0.29)	
PSPP eligible & purchased		-25.48		-10.80
		(-1.20)		(-0.51)
PSPP eligible & not purchased				55.52
				(1.26)
CSPP period			-41.32***	-40.99***
			(-4.56)	(-4.51)
CSPP eligible			21.27*	21.26*
			(1.73)	(1.73)
CSPP period × eligible			-27.18*	
			(-1.93)	
CSPP eligible & purchased		-45.32***		-26.01*
		(-3.27)		(-1.70)
CSPP eligible & not purchased				-32.69
				(-1.59)
Observations	5,545	5,545	5,545	5,545
Adjusted R-squared	0.134	0.133	0.144	0.144
Control Variables X_i	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes

t-statistics in parentheses
* p<0.1 ** p<0.05 *** p<0.01

Table 8: Cross-Sectional Regression to test for an APP Structural Change in Liquidity. This table displays the coefficients and the t-statistics for the cross-sectional regressions regarding the asset purchase programs.

	(1) Bid-Ask-Spread	(2) Bid-Ask-Spread	(3) Bid-Ask-Spread	(4) Bid-Ask-Spread
In-Crisis	3.54*	3.58*	6.38***	6.37***
	(1.69)	(1.70)	(2.95)	(2.95)
Post-Crisis	13.59***	13.63***	15.34***	15.32***
	(6.64)	(6.66)	(6.45)	(6.44)
ECB eligible & purchased	-5.97***			
	(-3.92)			
CBPP1 period			-6.32**	-6.31**
			(-2.14)	(-2.13)
CBPP1 eligible			-4.01	-4.03
			(-1.23)	(-1.24)
CBPP1 period × eligible			10.28***	10.28***
			(2.68)	(2.68)
CBPP2 period			8.48***	8.47***
			(3.71)	(3.70)
CBPP2/3 eligible			0.77	0.78
			(0.25)	(0.25)
CBPP2 period × eligible			6.78	6.77
			(1.23)	(1.22)
CBPP3 period			-1.01	-1.01
			(-0.60)	(-0.61)
CBPP3 period × eligible			-6.72***	-6.77***
			(-2.83)	(-2.85)
PSPP period			2.72	2.72
			(1.54)	(1.54)
PSPP eligible			-2.26	-2.27
			(-0.66)	(-0.66)
PSPP period × eligible			-7.59***	
			(-2.75)	
PSPP eligible & purchased		-7.86***		-7.40***
		(-3.80)		(-2.68)
PSPP eligible & not purchased				-10.03**
				(-2.48)
CSPP period			-3.40*	-3.41*
			(-1.81)	(-1.82)
CSPP eligible			-3.53	-3.53
			(-1.14)	(-1.14)
CSPP period × eligible			-1.55	
			(-0.93)	
CSPP eligible & purchased		-6.03***		-2.62
		(-3.39)		(-1.55)
CSPP eligible & not purchased				2.72
				(1.02)
Observations	5,424	5,424	5,424	5,424
Adjusted R-squared	0.278	0.278	0.286	0.286
Control Variables X_i	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes

t-statistics in parentheses
* p<0.1 ** p<0.05 *** p<0.01

A. Internet Appendix

Table A.1: Empirical Research on Underpricing in Corporate Bond Markets. This table summarizes 17 relevant empirical research papers and lists the market analyzed, the time period analyzed, the sample size, the pricing source for the bonds, the level of analysis, the index for the expected return model, the event window in trading days and the respective results. (Significance of results is indicated by * p<0.1 ** p<0.05 *** p<0.01.)

Study	Market	Time Period	Sample Size	Pricing Source	Level of Analysis	Index	Event Window	Result
Ederington (1974)	US	1964-1971	611	'Weekly Bond Buyer'	YTM	Corporate Bond Index	20	30.9 bps
Lindvall (1977)	US	1967-1972	103	S&P's Bond Guide	YTM	Corporate Bond Index	60	17.5 bps
Weinstein (1978)	US	1962-1974	179	[not given]	Returns	Matched Bond Portfolio	20	38.3 bps
Sorensen (1982)	US	1974-1980	880	'Institutional Investor'	YTM	Corporate Bond Index	15	8.4 bps***
Fung and Rudd (1986)	US	1983-1985	123	Shearson Lehman Bros.	Returns	Lehman Treasury Index	n/a	-25 bps
Wasserfallen et al. (1988)	Swiss	1980-1982	328	Zurich Stock Exchange	Returns	Matched Corporate Bond	3	53 bps***
Datta et al. (1997)	US	1989-1992	50	DRI / Tradeline	Returns	Matched Treasury Bond	60	IG: -67 bps Non-IG: 85 bps**
Hale and Santos (2006)	US	1995-2002	359	NAIC	YTM	Moody's yield indices	1	IBOs: 16 bps*** SBOs: 6 bps***
Cai et al. (2007)	US	1995-1999	2,957	NAIC	Returns	Lehman Brother's indices	5	IBOs: 35 bps*** SBOs: 13 bps***
Goldstein & Hotchkiss (2007)	US	2002-2006	3,181	TRACE	Returns	[no market adjustment]	5	IG: 45 bps*** Non-IG: 124 bps***
Goldberg and Ronn (2013)	US	2008-2012	1,494	TRACE	YTM	CFOX (BofAML index)	40	22.5 bps***
Liu and Magnan (2014)	US	2003-2009	414	TRACE	Returns	Matched US Treasury Bond	1	79 bps
Zaremba (2014)	CEE	2010-2013	142	Bloomberg	Returns	n/a	60	90 bps***
Aronsson and Tano (2016)	Swedish	2009-2016	256	Bloomberg	Returns	BofAML indices	5	IG: -17 bps*** Non-IG: 22 bps**
Mietzner et al. (2016)	German	2010-2013	135	Local Exchanges	Returns	[no market adjustment]	1	67 bps***
Helwege and Wang (2016)	US	2003-2011	1,384	TRACE	Returns	[no market adjustment]	5	Mega-Bonds: 115 bps***
Nagler & Ottonello (2017)	US	2003-2013	10,177	TRACE	Returns	FINRA Corp. Bond Index	10	Pre-Crisis: 23 bps*** In-Crisis: 72 bps*** Post-Crisis: 64 bps***

Table A.2: Summary Statistics.

Variable	N	Mean	SD	Min	Max
BID_CAR40	5579	40.9	158.92	-801.41	632.7
CAR40	5703	59.48	162.53	-485.61	635.56
ASK_CAR40	5579	82.4	164.18	-485.61	694.67
CAYC40	5684	-9.97	32.61	-230.83	469.69
Non-Financial Issuer	5703	0.37	0.48	0	1
SSA Issuer	5703	0.13	0.34	0	1
Covered Bond	5703	0.28	0.45	0	1
Subordinated Bond	5703	0.03	0.16	0	1
NA	5702	0.04	0.19	0	1
AA	5702	0.14	0.34	0	1
A	5702	0.25	0.43	0	1
BBB	5702	0.22	0.42	0	1
BB	5702	0.05	0.22	0	1
B	5702	0.02	0.15	0	1
CCC	5702	0	0.07	0	1
IBO	5703	0.15	0.36	0	1
Duration	5703	6.33	2.66	0.41	28.14
ln(Amount Issued)	5703	6.69	0.65	5.52	9.61
German Treasury Yield	5702	0.01	0.02	-0.01	0.05
Swap Spread	5702	0	0	0	0.01
10-day Δ Swap Spread	5698	0	0	0	0
Corporate Spread	5683	0.01	0.01	-0.01	0.1
10-day Δ Corporate Spread	5682	0	0	-0.02	0.01
SMOVE	5570	0.06	0.02	0.03	0.19
Own Underwriter	3570	0.09	0.29	0	1
Nr. of Bookrunners	3570	2.85	1.87	0	19
Top3-Underwriter	3570	0.34	0.47	0	1
In-Crisis	5703	0.05	0.23	0	1
Post-Crisis	5703	0.79	0.41	0	1
CBPP1 period	5703	0.08	0.26	0	1
CBPP1 eligible	5703	0.19	0.4	0	1
CBPP1 period $\times$ eligible	5703	0.02	0.14	0	1

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Table A.2 – continued from previous page

Variable	N	Mean	SD	Min	Max
CBPP2 period	5703	0.08	0.27	0	1
CBPP2/3 eligible	5703	0.19	0.39	0	1
CBPP2 period × eligible	5703	0.01	0.11	0	1
CBPP3 period	5703	0.33	0.47	0	1
CBPP3 period × eligible	5703	0.05	0.22	0	1
PSPP period	5703	0.29	0.45	0	1
PSPP eligible	5703	0.06	0.23	0	1
PSPP period × eligible	5703	0.01	0.11	0	1
CSPP period	5703	0.12	0.33	0	1
CSPP eligible	5703	0.19	0.39	0	1
CSPP period × eligible	5703	0.03	0.17	0	1
ECB eligible & purchased	5703	0.04	0.2	0	1
PSPP eligible & not purchased	5703	0	0.03	0	1
PSPP eligible & purchased	5703	0.01	0.1	0	1
CSPP eligible & not purchased	5703	0.01	0.08	0	1
CSPP eligible & purchased	5703	0.02	0.16	0	1

Table A.3: Underpricing measured as the CAAYC(0,40) by different panels. This table displays the number of observations (N), mean and t-statistic for $CAAYC(0,1)$, $CAAYC(1,40)$ and $CAAYC(0,40)$ among different subsamples.

		CAAYC(0,1)		CAAYC(1,40)		CAAYC(0,40)	
	N	Mean	t-stat	Mean	t-stat	Mean	t-stat
Complete Sample	5,684	5.236***	(22.31)	4.644	(12.81)	9.969	(23.05)
.							
Financial (Covered)	1573	1.158***	(4.05)	3.289***	(9.63)	4.446***	(9.81)
Financial (Senior)	1143	2.987***	(4.45)	-0.217	(-0.18)	2.770**	(2.09)
Financial (Subord.)	140	5.771***	(3.32)	6.434**	(2.16)	12.20***	(3.54)
Agency	573	2.535***	(4.54)	4.767***	(5.19)	7.302***	(6.68)
Supranational	174	1.774**	(2.25)	5.811***	(6.69)	7.585***	(6.85)
Non-Financial	2081	10.80***	(25.62)	8.316***	(15.85)	19.11***	(28.49)
Panel B: By Rating							
AAA	1565	0.750***	(2.83)	3.493***	(10.69)	4.243***	(10.07)
AA	774	2.623***	(5.54)	3.795***	(5.34)	6.417***	(7.32)
A	1416	5.465***	(12.91)	2.995***	(4.27)	8.461***	(10.33)
BBB	1278	8.549***	(17)	5.518***	(6.89)	14.07***	(14.98)
BB	282	13.65***	(9.42)	10.58***	(4.57)	24.23***	(9)
B	135	22.07***	(9.64)	17.66***	(4.9)	39.72***	(10.2)
CCC	25	11.71**	(2.08)	5.887	(0.42)	17.6	(1.32)
NA	208	6.115**	(2.08)	8.149**	(2.29)	14.26***	(3.31)
Panel C: By IBO/SBO							
IBO	849	11.66***	(16.71)	8.787***	(9.81)	20.45***	(17.84)
SBO	4835	4.213***	(16.92)	4.015***	(10.58)	8.228***	(18.45)
Panel D: By Time Period							
Pre-Crisis	875	0.193	(0.48)	2.775***	(7.57)	2.969***	(5.46)
In-Crisis	307	6.832***	(5.31)	12.83***	(8.09)	19.66***	(9.75)
Post-Crisis	4502	6.221***	(22.62)	4.555***	(10.81)	10.78***	(21.65)
Panel E: By Asset Purchase Program Eligibility							
CBPP1	116	3.471***	(3.97)	5.974***	(3.69)	9.445***	(5.33)
CBPP2	72	7.384***	(3.93)	0.655	(0.24)	8.039**	(2.41)
CBPP3	281	2.240***	(4.77)	3.382***	(7.93)	5.622***	(8.7)
PSPP	65	2.583***	(2.88)	5.276***	(5.18)	7.859***	(5.98)
CSPP	177	4.574***	(5.65)	5.573***	(6.74)	10.15***	(8.46)
None	4973	5.576***	(20.86)	4.797***	(12.16)	10.37***	(21.97)

t-statistics in parentheses

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

Table A.4: Underpricing measured as the CAAR(0,40) with bid-quotes by different panels. This table displays the number of observations (N), mean and t-statistic for $CAAR(0,1)$, $CAAR(1,40)$ and $CAAR(0,40)$ among different subsamples.

		CAAR(0,1)		CAAR(1,40)		CAAR(0,40)	
	N	Mean	t-stat	Mean	t-stat	Mean	t-stat
Complete Sample	5,579	16.11***	(12.45)	24.99***	(14.28)	40.90***	(19.22)
Panel A: By Issuer Type							
Financial (Covered)	1529	-6.450***	(-3.80)	6.740***	(2.95)	-0.135	(-0.05)
Financial (Senior)	1080	5.013*	(1.66)	5.352	(1.29)	10.51**	(2.22)
Financial (Subord.)	129	30.08**	(2.33)	44.68**	(2.52)	70.01***	(3.43)
Sub-Sovereign	567	1.031	(0.29)	31.59***	(5.49)	32.82***	(5.10)
Agency	173	5.113	(0.86)	45.68***	(4.58)	49.60***	(4.25)
Non-Financial	2060	42.86***	(18.17)	44.04***	(14.15)	87.27***	(22.88)
Panel B: By Rating							
AAA	1524	-7.648***	(-4.54)	10.64***	(4.36)	2.382	(0.80)
AA	759	6.357**	(2.24)	27.73***	(6.60)	33.62***	(6.76)
A	1388	19.13***	(7.51)	15.17***	(4.58)	34.14***	(8.17)
BBB	1267	31.23***	(11.67)	28.95***	(7.55)	60.24***	(13.14)
BB	276	54.91***	(6.96)	64.78***	(6.15)	119.7***	(10.02)
B	129	82.32***	(6.14)	134.8***	(7.38)	218.8***	(11.05)
CCC	22	26.31	(0.88)	100.3	(1.53)	131.2**	(2.34)
NA	172	20.18	(1.44)	35.50**	(2.36)	57.44***	(3.28)
Panel C: By IBO/SBO							
IBO	836	45.15***	(11.37)	48.16***	(9.54)	93.62***	(14.80)
SBO	4702	10.94***	(8.19)	20.87***	(11.29)	31.56***	(14.26)
Panel D: By Time Period							
Pre-Crisis	843	-4.710*	(-1.75)	7.730**	(2.52)	1.499	(0.36)
In-Crisis	304	21.64***	(3.92)	64.27***	(8.70)	84.99***	(9.12)
Post-Crisis	4391	19.72***	(13.21)	25.58***	(12.45)	45.59***	(18.52)
Panel E: By Asset Purchase Program Eligibility							
CBPP1	108	1.937	(0.53)	17.17*	(1.71)	19.10*	(1.76)
CBPP2	70	12.79	(1.18)	1.852	(0.11)	14.64	(0.71)
CBPP3	281	0.486	(0.13)	9.381**	(2.46)	9.867*	(1.87)
PSPP	65	6.793	(0.72)	28.13*	(1.90)	34.92*	(1.96)
CSPP	177	19.14***	(2.84)	32.53***	(4.83)	51.67***	(5.50)
None	4837	17.39***	(12.19)	26.09***	(13.47)	43.24***	(18.44)

t-statistics in parentheses

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

Table A.5: Cross-Sectional Regressions as Robustness Checks. This table displays detailed regression results for the robustness checks of the final specification. Model (2) is the final specification using mid-quotes. Model (1) and (3) display the results for using bid- and ask-quotes. Model (4) incorporates the $CAYC_i(0, 40)$ as the dependent variable.

	(1) BID_CAR(0,40)	(2) CAR(0,40)	(3) ASK_CAR(0,40)	(4) CAYC(0,40)
Non-Financial Issuer	29.32***	37.21***	33.50***	8.21***
	(2.95)	(3.71)	(3.33)	(3.65)
SSA Issuer	3.41	12.81	14.09	0.71
	(0.29)	(1.06)	(1.17)	(0.28)
Covered Bond	-9.06	-0.99	-1.00	3.92*
	(-0.88)	(-0.09)	(-0.09)	(1.70)
Subordinated Bond	70.16***	73.80***	70.26***	17.19***
	(2.64)	(2.66)	(2.68)	(3.52)
NA	49.30**	53.37**	80.40***	15.34***
	(2.21)	(2.56)	(3.60)	(2.84)
AA	20.76***	21.49***	24.08***	3.24**
	(3.20)	(3.12)	(3.49)	(2.50)
A	16.66*	22.41**	22.95**	7.45***
	(1.71)	(2.21)	(2.30)	(3.92)
BBB	39.73***	45.49***	45.25***	13.26***
	(3.37)	(3.86)	(3.76)	(5.75)
BB	98.85***	110.90***	122.69***	19.76***
	(5.29)	(6.00)	(6.52)	(5.37)
B	191.01***	208.49***	231.94***	34.36***
	(6.73)	(7.30)	(8.34)	(5.99)
CCC	107.38	120.95	156.77*	12.41
	(1.29)	(1.45)	(1.94)	(0.60)
IBO	26.34***	28.66***	28.56***	5.54***
	(3.29)	(3.55)	(3.56)	(3.72)
Duration	5.73**	6.80***	6.96***	-0.51
	(2.58)	(3.05)	(3.07)	(-1.25)
ln(Amount Issued)	13.20***	13.18***	6.64	3.39***
	(3.04)	(2.76)	(1.54)	(3.54)
German Treasury Yield	-81.33	-88.15	-94.79	-12.15
	(-1.30)	(-1.40)	(-1.47)	(-1.19)
Swap Spread	932.30**	980.11**	1073.23**	247.29***
	(2.16)	(2.29)	(2.51)	(3.43)
10-day Delta Swap Spread	1728.98	2075.13**	2006.30*	180.50
	(1.64)	(1.98)	(1.93)	(0.90)
Corporate Spread	-294.06***	-258.22***	-201.55***	-97.32***
	(-4.49)	(-4.09)	(-3.19)	(-7.38)
10-day Delta Corporate Spread	315.99	203.37	330.33	78.85
	(0.61)	(0.39)	(0.64)	(0.57)
SMOVE	8.75	25.78	47.26	6.91
	(0.29)	(0.84)	(1.53)	(1.39)

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Table A.5 – continued from previous page

	(1) BID_CAR(0,40)	(2) MID_CAR(0,40)	(3) ASK_CAR(0,40)	(4) CAYC(0,40)
In-Crisis	97.83***	103.95***	104.42***	17.12***
	(7.75)	(8.13)	(8.14)	(6.22)
Post-Crisis	21.23*	30.73***	37.62***	6.90***
	(1.86)	(2.73)	(3.30)	(3.54)
CBPP1 period	26.22**	18.13	19.75	1.01
	(2.07)	(1.41)	(1.54)	(0.32)
CBPP1 eligible	-28.40**	-29.13**	-34.89***	-1.48
	(-2.52)	(-2.44)	(-2.86)	(-0.76)
CBPP1 period × eligible	13.30	22.28	25.94	6.53*
	(0.76)	(1.32)	(1.46)	(1.82)
CBPP2 period	35.04***	38.68***	42.90***	0.40
	(2.64)	(3.00)	(3.18)	(0.10)
CBPP2/3 eligible	36.06***	35.95***	37.95***	1.30
	(3.21)	(3.25)	(3.19)	(0.69)
CBPP2 period × eligible	-4.70	-1.59	4.18	8.45**
	(-0.21)	(-0.07)	(0.18)	(2.16)
CBPP3 period	19.90	18.92	18.85	-4.51**
	(1.59)	(1.49)	(1.45)	(-2.06)
CBPP3 period × eligible	-17.20*	-20.59**	-23.53**	-1.12
	(-1.83)	(-2.18)	(-2.39)	(-0.71)
PSPP period	-11.37	-9.67	-9.24	4.04**
	(-1.00)	(-0.84)	(-0.79)	(2.01)
PSPP eligible	-10.28	-14.42	-13.75	-1.94
	(-0.87)	(-1.16)	(-1.13)	(-0.85)
PSPP period × eligible	-3.08	-5.71	-11.71	1.05
	(-0.15)	(-0.29)	(-0.57)	(0.47)
CSPP period	-40.44***	-41.32***	-43.77***	-4.95***
	(-4.46)	(-4.56)	(-4.73)	(-3.61)
CSPP eligible	26.30**	21.27*	20.66*	5.88**
	(2.14)	(1.73)	(1.75)	(2.48)
CSPP period × eligible	-24.45*	-27.18*	-27.00*	-10.22***
	(-1.72)	(-1.93)	(-1.90)	(-4.72)
Observations	5,425	5,545	5,425	5,545
Adjusted R-squared	0.120	0.144	0.173	0.099
Clustered SE	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes

t-statistics in parentheses

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

Table A.6: Cross-Sectional Regressions as Robustness Checks. This table displays detailed regression results for our results using a winsorized sample (1% / 99%) rather than a trimmed sample. Model (2) is the final specification using mid-quotes. Model (1) and (3) display the results for using bid- and ask-quotes. Model (4) incorporates the $CAYC_i(0, 40)$ as the dependent variable.

	(1) BID_CAR(0,40)	(2) CAR(0,40)	(3) ASK_CAR(0,40)	(4) CAYC(0,40)
Non-Financial Issuer	28.99**	44.19***	32.79***	10.30***
	(2.34)	(4.01)	(2.70)	(3.34)
SSA Issuer	-0.04	14.48	10.42	-1.89
	(-0.00)	(1.11)	(0.68)	(-0.47)
Covered Bond	-3.41	4.12	4.77	6.15**
	(-0.27)	(0.35)	(0.38)	(2.04)
Subordinated Bond	69.14**	73.98***	69.95**	23.40***
	(2.37)	(2.76)	(2.40)	(3.37)
NA	65.83**	52.42**	97.55***	13.30
	(2.33)	(2.41)	(3.86)	(1.55)
AA	27.46***	25.48***	31.04***	4.62***
	(3.15)	(3.13)	(3.45)	(2.83)
A	35.76***	31.60***	42.75***	12.83***
	(2.72)	(2.76)	(3.26)	(3.70)
BBB	65.99***	60.39***	72.96***	21.97***
	(3.94)	(4.52)	(4.36)	(4.72)
BB	129.67***	126.40***	155.01***	27.41***
	(5.48)	(6.35)	(6.68)	(4.76)
B	199.31***	218.94***	243.25***	37.25***
	(4.41)	(6.48)	(5.55)	(3.99)
CCC	289.85***	243.09***	336.57***	45.47**
	(2.94)	(2.77)	(3.49)	(2.01)
Duration	7.06**	7.35***	8.16**	-0.33
	(2.13)	(2.64)	(2.44)	(-0.50)
ln(Amount Issued)	19.15***	18.45***	12.65**	5.31***
	(3.52)	(3.56)	(2.37)	(4.73)
IBO	38.16***	32.96***	40.31***	6.99***
	(3.61)	(3.59)	(3.84)	(3.23)
German Treasury Yield	-195.90**	-137.79*	-203.37**	-40.45*
	(-2.27)	(-1.93)	(-2.33)	(-1.95)
Swap Spread	1041.10	930.97*	1140.94*	345.11***
	(1.61)	(1.69)	(1.78)	(2.58)
10-day Delta Swap Spread	2422.55*	2683.21**	2692.38*	45.51
	(1.73)	(2.20)	(1.93)	(0.12)
Corporate Spread	-522.59***	-406.08***	-448.09***	-182.97***
	(-3.59)	(-5.51)	(-3.08)	(-2.97)
10-day Delta Corporate Spread	720.05	327.48	745.28	270.59
	(0.87)	(0.55)	(0.89)	(0.93)
SMOVE	65.06*	55.38	105.66***	19.50**
	(1.67)	(1.59)	(2.60)	(2.34)

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Table A.6 – continued from previous page

	(1) BID_CAR(0,40)	(2) MID_CAR(0,40)	(3) ASK_CAR(0,40)	(4) CAYC(0,40)
In-Crisis	144.00***	132.33***	151.52***	29.33***
	(6.87)	(7.91)	(7.22)	(5.81)
Post-Crisis	15.26	33.43**	34.52**	6.01
	(0.91)	(2.49)	(2.05)	(1.20)
CBPP1 period	47.22***	24.43*	40.56***	3.33
	(3.21)	(1.79)	(2.75)	(0.87)
CBPP1 eligible	-25.38**	-27.84**	-31.85**	-0.66
	(-2.03)	(-2.18)	(-2.37)	(-0.28)
CBPP1 period × eligible	6.56	17.41	18.61	6.40
	(0.35)	(0.95)	(0.96)	(1.50)
CBPP2 period	40.25**	42.97***	49.48**	-0.84
	(2.06)	(2.66)	(2.49)	(-0.18)
CBPP2/3 eligible	31.80**	33.08***	33.88**	-1.76
	(2.41)	(2.75)	(2.47)	(-0.61)
CBPP2 period × eligible	0.57	1.03	10.03	14.21***
	(0.02)	(0.04)	(0.35)	(2.82)
CBPP3 period	13.96	16.58	13.55	-7.79***
	(0.98)	(1.23)	(0.92)	(-2.86)
CBPP3 period × eligible	-21.17*	-23.44**	-28.07**	-2.07
	(-1.91)	(-2.33)	(-2.46)	(-0.73)
PSPP period	-11.39	-9.42	-9.61	4.66**
	(-0.93)	(-0.78)	(-0.76)	(2.06)
PSPP eligible	-10.69	-19.44	-14.45	-3.44
	(-0.67)	(-1.26)	(-0.87)	(-1.21)
PSPP period × eligible	-53.86***	-39.22**	-64.87***	-2.36
	(-2.59)	(-1.96)	(-3.06)	(-0.81)
CSPP period	-37.53***	-37.18***	-40.29***	-5.14***
	(-3.43)	(-3.57)	(-3.63)	(-2.81)
CSPP eligible	27.63*	19.78	22.43	3.93
	(1.87)	(1.48)	(1.59)	(1.17)
CSPP period × eligible	-38.41**	-37.87**	-40.94**	-13.96***
	(-2.40)	(-2.51)	(-2.55)	(-5.38)
Observations	5520	5658	5520	5658
Adjusted R-squared	0.118	0.151	0.154	0.100
Control Variables Xi	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Weekday FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes

t-statistics in parentheses
* p<0.1 ** p<0.05 *** p<0.01

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