Heterogeneous Intermediaries and the Transmission(s) of Monetary Policy *

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Abstract

This paper studies the transmission of monetary policy to the corporate bond market. We show that corporate bond purchases by the central bank give rise to credit spread shocks, whereas government bond purchases mainly cause term spread shocks. The yields of bonds held by different intermediaries respond heterogeneously to the two shocks because intermediaries systematically select into different types of bonds. We explain these findings through the lens of a model of the fixed-income market with multiple risk factors. Insurance companies and pension funds select into assets with high interest-rate risk exposure to match their long-duration liabilities. The mutual fund sector instead absorbs securities that carry credit risk. Different policy tools affect the market prices of risk factors in a differential manner, thereby redistributing risks across intermediary sectors and ultimately across the households investing in them.

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1. Introduction

Over the past two decades, central banks have engaged in various asset purchase programs, also known as Quantitative Easing (QE), to lower the borrowing costs faced by businesses and households and, ultimately, stimulate the economy. The standard view among policymakers and researchers is that QE affects asset prices through its impact on the balance sheets of financial intermediaries. However, different intermediary asset pricing models have different implications for the effects of intermediaries on the *cross section* of asset prices and, therefore, the transmission of QE.

One view highlights the role of investor heterogeneity on valuation. When there are limits to arbitrage, two bonds with similar payoffs could be valued differently if they are held by mutual funds than when they are held by insurance companies. QE affects prices of individual bonds the central bank trades with intermediaries. It has narrow effects on bond prices that depend on which intermediary holds the bond. Another view holds that bond prices reflect a small number of risk factors or characteristics that intermediaries are exposed to. QE can reduce intermediaries' exposure to a factor and thereby the price of the factor. It thus has broad effects on all bonds exposed to the factor.

This paper provides new evidence about the cross-sectional effects of monetary policy shocks on corporate bond prices. We leverage an ECB confidential dataset on security-level portfolio holdings by the leading investors in corporate bonds: mutual funds, insurance companies and pension funds (ICPFs). We first show that ECB policy can target different segments of the bond market. In particular, when the central bank buys corporate bonds, the transmission of policy works through credit spreads and mainly affects bonds held by mutual funds. In contrast, when the central bank buys government bonds, transmission works through term spreads and mainly affects bonds held by insurance companies and pension funds. We further show that the price response is explained by characteristics of the bonds and not by the characteristics of the intermediary holding the bonds. The association between price response and intermediary portfolios originates from a selection effect: financial intermediaries systematically select themselves into different assets because of their characteristics.

We rationalize our findings by building on a long tradition of thinking about fixed-income markets in terms of a small number of risk factors. Two factors—interest-rate risk and credit risk explain a large chunk of the variation in fixed-income prices (Fama and French 1993). As a result, intermediaries' fixed income portfolios can be summarized by their factor exposures (Begenau, Piazzesi, and Schneider 2015). The implication for monetary policy is that both bond prices and intermediary portfolios respond differently depending on which factor price the central bank targets. Bonds with a high loading on credit risk are naturally more exposed to the QE credit shock, while bonds with a high loading on interest-rate risk exhibit higher sensitivity to the QE interest rate shocks. Intermediaries choose different bonds due to their liability structure and regulatory framework: Insurance companies and pension funds select bonds with high interest-rate risk exposure to match their long-duration liabilities. Mutual funds instead absorb credit risk. This selection mechanism exposes their balance sheets to different types of QE policies in accordance with our empirical findings.

Taken together, our paper suggests that a factor approach is useful for thinking about the effects of QE. The Euro area provides an interesting case for understanding the monetary policy transmission of different instruments. Like many other central banks, the ECB has included various asset classes in the purchase programs adopted to counter disinflationary pressures since mid-2014. In addition to securities issued by the government sector, these have also comprised corporate bonds, with the latter accounting for the second most significant component of the purchase envelope since their introduction in 2016. In this paper, we study the effects of the ECB monetary policy on the Euro area corporate bond market, combining a set of novel empirical findings with an asset pricing model of the fixed-income market.

First, we construct monetary policy shocks. We define the *term spread monetary policy shock* as the high-frequency change in OIS term spreads (the difference between 10-year and 2-year OIS rates) in a narrow window around ECB monetary policy announcements. The *credit spread monetary policy shock* is defined as the change in a credit spread index within a two-day window around ECB policy announcements. We construct the index "bottom-up" from individual bond prices, subtracting from each bond yield the maturity-matched OIS rate. As a result, the credit spread shock does not reflect policy-induced changes in term-premium. The resulting shock series summarizes the impact of ECB policy on credit risk for the period 2014-2021.

We further show that the prevalence of these two shocks depends on the design of central bank asset purchase programs. ECB announcements related to government bond purchases primarily give rise to term spread shocks (Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa 2019, Eser et al. 2019, Swanson 2021), whereas announcements related to corporate sector purchases primarily give rise to credit spread shocks. The main takeaway from the new shock series is that the ECB can affect credit risk separately from interest rates through its communication with the markets. The new credit spread shocks series has a low correlation (close to zero) with the term spread shock or shocks to the 2-year OIS rate (a standard measure of monetary policy shocks; e.g., Hanson and Stein 2015). For example, a significant negative shock was the first announcement of ECB corporate purchases in March 2016, which lowered the spread index by more than 15bp. At the same time, the value-weighted interest on the bonds in our index increased.

Second, using these shocks, we estimate the cross-sectional effects of monetary policy on the corporate bond market. To this end, we group corporate bonds according to key characteristics: maturity, rating, and sector. For each group, we estimate the sensitivity of the variation in their credit spread around ECB announcements to our credit spread monetary policy shock. Using proprietary data from the ECB, we also match every single bond with the intermediary sectors by which they are held (e.g., mutual funds, insurance companies, and pension funds). This sorting, in turn, exposes a strong correlation between the holdings of different intermediaries and the sensitivity coefficients. Bonds held by mutual funds exhibit higher sensitivity to the credit spread shock, whereas bonds held by insurance companies and pension funds are less sensitive to the shock. In other words, when the monetary policy lowers credit spreads, it boosts the portfolios of mutual funds relative to those of insurance companies and pension funds. We find that a 50% increase in the shares held by mutual funds doubles the effect of our credit spread monetary policy shock on bond spreads. A one basis point positive credit spread shock leads to a 3bps increase in the spread of a bond entirely held by mutual funds. The same shock prompts a one basis point increase in the spread on a bond entirely held by insurance companies and pension funds. The opposite result obtains in an analogous exercise where we use the term spread shock: When the ECB lower term spreads, it boosts the portfolios of insurance companies and pension funds relative to those of mutual funds.

How do we explain these results? One possibility is that the ownership effect on single securities generates the empirical correlation between holdings and sensitivity to shocks. In that line of reasoning, quantitative easing policies affect a specific asset price because of its impact on the balance sheet of the intermediaries that are relevant to that market. The potential differential impacts on the balance sheets of mutual funds and insurance companies and companies lead to heterogeneous effects on corporate bonds. Coppola (2021) highlights the impact of the investor base composition on the dynamics of corporate bond prices during recessions. Using the same methodology, we find that the characteristics of corporate bonds explain most of the heterogeneity in the price response to monetary policy shocks. We show that the ownership effect vanishes once we control for enough bond characteristics, such as credit rating, issuer sector, or issuer identity. Even more importantly, we show that the ex-ante credit spread is sufficient statistics to explain the response of bonds to our monetary policy shocks. We show that once we control for the credit spread of the bond, the ownership effect vanishes. This result informs the anatomy of the transmission.

Our results suggest that the credit risk of bonds is sufficient statistics for the cross-sectional effects of our monetary policy shocks. The results also have several implications. Euro area countries are characterized by different financial industries. The transmission to bonds with similar credit risk but issued by different countries would have different price reactions because the shares of intermediaries holding them are different. However, our results show that this is not the case. Two corporate bonds with similar risk exposure exhibit similar price reactions. An alternative channel is that mutual funds and insurance companies and pension funds hold bonds with different liquidity and this is causing the differential effect. We show that the differential liquidity of the bonds explains only a small share of the different price responses of bonds held by different intermediaries.

Our results instead point to a factor approach to thinking about intermediary portfolios and QE. Begenau, Piazzesi, and Schneider (2015) represent intermediary portfolios by factor exposures to interest rate risk and credit risk. They emphasize that factor exposures capture intermediary risk better than many balance-sheet based measures because they naturally handle exposure due to derivatives positions such as banks' interest rate swap portfolios. Papoutsi, Piazzesi, and Schneider (2021) propose a model of unconventional monetary policy where central bank purchases change factor prices because they lower private intermediaries' marginal cost of holding risky bonds. In particular, they show that central banks can affect carbon emissions by trading a climate risk factor since the price of that factor moves polluting firms' cost of capital.

Our third contribution is a model of the bond market that clarifies the transmission of policy shocks through heterogeneous intermediaries. The model features two types of intermediaries: Some financial intermediaries do not have the technology to borrow (asset managers), others have the technology to borrow but are regulated based on how much risk they have in their portfolio (as in Koijen and Yogo (2022) for insurance companies and pension funds). Since levered intermediaries are funded with long-term debt, they are exposed to interest rate risk on the liability side of their balance sheet— an essential ingredient of our model. We also assume two types of households: Passive investors save exclusively in long-term debt issued by levered intermediaries, whereas active investors have access to asset management shares and equity in levered intermediaries.

Levered intermediaries, asset managers, and the central bank all choose their bond portfolios. We characterize bond portfolios as exposures to two risky assets in nonzero net supply. The stream of payments of the first asset depends on the realization of the interest risk factor (i.e., a portfolio of long-term bonds with low default risk). The stream of payments of the second asset depends on the realization of the credit risk factor (i.e., a portfolio of bonds with high default risk). The central bank also issues safe debt and uses lump sum rebates on both investor types to reconcile its risky asset income with its safe debt obligations.

Overall, an equilibrium consists of (i) asset prices, (ii) portfolios of private intermediaries, the central bank and households, and (iii) household consumption. We can then consider the cross-section of bond prices in the data as linear combinations of the two asset prices (based on the bond exposure to interest-rate risk and credit). The model provides a set of predictions on allocations, asset prices, and the transmission of monetary policy.

Levered intermediaries endogenously select into interest rate risk. By doing so, they match the risk exposure of their assets and liabilities and lower their regulatory cost. However, it is costly for levered intermediaries to hold credit risk, which endogenously explains mutual funds' relatively higher credit risk exposure. Central bank purchases of either type of risk affect the intermediary shareholders' stochastic discount factor and, thereby, the price of the risk factor under consideration. Central bank absorption of credit risk boosts mutual fund portfolios and lowers the market price of credit risk. Central bank absorption of interest rate risk boosts insurance portfolios and lowers the market price of interest rate risk.

There are costs involved in the purchase program since it indirectly forces passive households-which do not participate in risky asset markets- to participate through future central bank rebates. This redistribution of risk from the active investor to the passive investor gives rise to price effects, a mechanism studied by Silva (2016). The crucial difference is that, in our model, it is not only the quantity of risk absorbed by the central bank that matters but also the composition of such risk.

Finally, we provide empirical evidence to corroborate the predictions of our model. We sort corporate bonds based on their credit spread and maturity. We use the ECB granular holdings database to show that levered intermediaries mainly sort into high interest-rate risk and low credit-risk assets, while mutual funds sort into credit risky assets. Consistent with our factor approach, bonds with higher credit spreads (i.e., higher β loadings on credit risk) are more sensitive to credit spread monetary policy shocks. We also provide further evidence based on the effects of two specific announcements: the Corporate Sector Purchase Programme announcement (CSPP) and the Pandemic Emergency Purchase Programme (PEPP) announcement. We show that sub-investment grade corporate bonds, which were ineligible to be purchased by the ECB, exhibited strong price responses to both announcements. This evidence contrasts with previous findings on the effects of the Federal Reserve's announcement of corporate bond purchases (e.g., Haddad, Moreira, and Muir 2021). It highlights the relevance of the factor approach for a broader understanding of the transmission of quantitative easing.

Our results have important implications for the transmission of monetary policy, financial stability, and redistribution. First, the results suggest that the asset price effects of monetary policy primarily depend on the type of monetary policy shock (i.e., the type of risk factor absorbed: credit risk or interest-rate risk) and the exposure of the bond to the different risk factors, based on its characteristics. Once we account for the characteristics of the bond, the investor base composition of the individual bond has minor effects on the transmission of shocks to asset prices. Second, different monetary policy shocks have significantly different effects on the balance sheets of different intermediaries. A quantitative easing or tightening operated via corporate bonds significantly affects the balance sheets of mutual funds and the funding costs of credit-riskier non-financial corporations. A quantitative easing or tightening operated via buying or selling government bonds mainly affects the balance sheets of insurance companies and pension funds and the borrowing costs of safer non-financial corporations. Third, different central banks' purchases have different redistributive effects across households. The entire household sector ultimately bears the risks on the central bank's balance sheet. A quantitative easing or tightening redistributes risks from intermediary shareholders to the household sector as a whole.

1.1 Literature Review

By providing empirical evidence and new theoretical insights on the transmission mechanism of different central bank policies, we contribute to the vast literature on large-scale asset purchases and the role of intermediaries. From an empirical perspective, Krishnamurthy and Vissing-Jorgensen (2011), Gagnon, Raskin, Remache, and Sack (2011) take an event study approalso been studiedeffects of QE on asset prices. Several papers also investigate the transmission of QE on asset prices in the Euro area, including Krishnamurthy, Nagel, and Vissing-Jorgensen (2017), Altavilla, Carboni, and Motto (2015); Leombroni, Vedolin, Venter, and Whelan (2021). Our paper also focuses on the effects of ECB corporate bond purchases. We hence relate to a relevant set of papers that investigate the impact of the announcement of ECB CSPP (Corporate Sector Purchase Programme) (Abidi and Miquel-Flores 2018; De Santis, Geis, Juskaite, and Cruz 2018; Grosse-Rueschkamp, Steffen, and Streitz 2019; Zaghini 2020; Todorov 2020; De Santis and Zaghini 2021). A set of different papers also studied the effects of Fed bond marekt stimulus (Haddad, Moreira, and Muir 2021,Darmouni and Siani 2022). In our paper, we take a systematic approach by constructing two monetary policy shocks, one affecting credit spreads and the other affecting term spreads. We then show that corporate bond purchases by the central bank mainly give rise to credit spread shocks. We also show that government bond purchases mainly cause term spread shocks, by relating our shocks to the previous work of Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) and Swanson (2021). Leombroni, Vedolin, Venter, and Whelan (2021) discusses the effects of different monetary policy shocks on the Euro area government bond market using high-frequency movements of default-free rates and equity; the paper also shows that monetary policy communications by the European Central Bank led to a significant yield spread between peripheral and core countries during the European sovereign debt crisis by increasing credit risk premia.

Credit spreads are an essential determinant of economic activity (Gilchrist and Zakrajšek 2012) and a crucial channel for monetary policy transmission (Gertler and Karadi 2011). Central banks can affect credit spreads either through their interest rate policies (Gertler and Karadi 2015, Gilchrist, López-Salido, and Zakrajšek 2015) or directly through a new set of policy interventions (e.g., corporate sector purchases). This second channel motivates our new credit spread monetary policy shocks. We show that while ECB corporate bond purchases substantially affect credit spreads, interest rate policies' effects on credit spreads are limited.

We then study the effects of the two shocks to the cross-section of corporate bond yields. Many papers have studied the cross-sectional effects of monetary policy (measured through the change in interest rate) on corporate bonds, including Gilchrist, López-Salido, and Zakrajšek (2015), Gertler and Karadi (2015), Smolyansky and Suarez (2021), Anderson and Cesa-Bianchi (2020). We extend this earlier work by (i) studying new monetary policy shocks and (ii) relating the cross-sectional effects to intermediary holdings. We show that yield on bonds held by different intermediaries responds heterogeneously to the two shocks.

However, this heterogeneity in responses primarily reflects bond characteristics rather than the investor base composition for a given bond. We emphasize the factor structure in fixed-income assets (Fama and French 1993) and discuss how different β loadings on different risk factors explain the cross-sectional response of corporate bonds. Factor models of the corporate bond market have been studied also by Kelly, Palhares, and Pruitt (2020), Bai, Bali, and Wen (2019).

Our result extends the work of Coppola (2021) to different types of shock, i.e., monetary policy shocks. Faia, Salomao, and Veghazy (2022) also stresses how institutional investors' mandates determine bond demand, which, through granularity, affects bond prices. Siani (2021) estimates a model of differentiated investors in segmented primary bond markets. An elevated degree of relative mispricing for nearly identical bonds indicates the presence of some persistent limits to arbitrage in the corporate bond market. Limits to arbitrage may be supported, for example, by search and matching frictions, given the over-the-counter (OTC), decentralized nature of the corporate bond market (Duffie, Gârleanu, and Pedersen 2005, Duffie, Gârleanu, and Pedersen 2007). Two bonds can be valued differently depending on the intermediaries holding them (e.g., Feldhütter 2012). It is not uncommon to find mispricing of similar securities during a crisis (Duffie 2010, Du, Tepper, and Verdelhan 2018) even for extremely liquid assets such as U.S. Treasury bonds. Segmented market models have been studied in fixed income (Mitchell, Pedersen, and Pulvino 2007, Hu, Pan, and Wang 2013, Greenwood and Vayanos 2014, Siriwardane 2019) and equity markets (Greenwood and Thesmar 2011, Anton and Polk 2014). Greenwood, Hanson, and Liao (2018) studies a model in which capital moves quickly within an asset class but slowly between asset classes.

In our work we then emphasize how heterogeneous intermediaries systematically select into different types of assets. Koijen and Yogo (2022) discusses the equilibrium allocation of insurance companies in a model with different intermediaries where insurance companies have relatively cheap access to leverage through their underwriting activity. Other papers have instead emphasized the importance of duration matching for the insurance sector (for instance, Domanski, Shin, and Sushko 2017, Ozdagli and Wang 2022, Carboni and Ellison 2022).

We extend the framework of Koijen and Yogo (2022) to a dynamic asset pricing model where the debt of insurance companies and pension funds is risky. Intermediaries allocate across two risk factors: interest rate risk and credit risk. We hence emphasize the portfolio choice across different risk factors, the importance of liabilities hedging for asset allocation, and the equilibrium risk premia commanded on different risks.[1] Finally, we also use the framework to study the effects of central banks purchases.

A growing literature has emphasized the role of investor heterogeneity in asset pricing. Coimbra and Rey (2017), Ma (2017) and Kargar (2021) develop asset pricing models with investor heterogeneity. Koijen and Yogo (2019) proposes a model with flexible heterogeneity in asset demand across investors, and Bretscher, Schmid, Sen, and Sharma (2021) applies this methodology to corporate bonds. Koijen, Koulischer, Nguyen, and Yogo (2021) uses this approach to evaluate the impact of ECB QE on asset pricing using the ECB SHS database. We take a different ap-

[1] Our model shows that the size of the insurance sector affects the interest rate risk premium, consistently with the work of Greenwood and Vissing-Jorgensen (2018)

proach by studying the systematic effects of different monetary policy shocks on the cross-section of corporate bonds around ECB announcements and then discuss how bonds held by different intermediaries are exposed to the different shocks and how different policy instruments have different cross-sectional implications.

These empirical findings motivate a modeling framework where central banks affect the market price of different risk factors; the cross-sectional effects are then pinned down by the different exposure of corporate bonds to the two risk factors (based on bond characteristics). The risk redistribution channel (based on a single risk factor) was introduced by Silva (2016). Our theoretical approach contributes to the extensive literature on quantitative easing (Gertler and Karadi 2011, He and Krishnamurthy 2013, Brunnermeier and Sannikov 2014, Piazzesi and Schneider 2021, Vayanos and Vila 2021) as well other studies on the role of conventional monetary policy for risk premia (Kekre and Lenel 2021).

2. The Euro Area Corporate Bond Market

The Euro area corporate bond market has been growing over the past two decades and is increasing its role in the debt financing of non-financial corporations.[2] Bank loans have historically been the primary source of debt financing for firms in the Euro area. However, the corporate bond market is gaining share: In 2021, corporate bonds accounted for 15% of non-financial corporations' long-term debt financing.[3] Figure 1a shows the rising share of market financing for non-financial corporations. The figure also shows how bond financing is even more relevant during recessions (the shaded area in Figure 1a), when access to bank loans may be impaired.

The leading investors in corporate bonds issued by Euro area non-financial corporations are mutual funds, insurance companies and pension funds (ICPF), banks, and the ECB.[4] At the end of 2021, the total amount of bonds held by Euro area investors totaled €1.36Tn. The largest Euro area investors in corporate bonds were mutual funds (34.7%), followed by ICPFs (27.2%). Of the total amount held by ICPFs, insurance corporations account for 89% while pension funds for the remaining 11%. The third largest investor is the ECB, which at the of 2021 held 18%. Finally, banks held 11%. The rest of the world holds an additional €0.35Tn. Figure 1b splits the amount of long-term corporate bonds issued by Euro area non-financial corporations and held by Euro area investors. Appendix A provides further information on the corporate bond market and the regulation of different intermediaries.

[2] See Darmouni and Papoutsi (2022) for a discussion on the rise of bond financing in Europe.

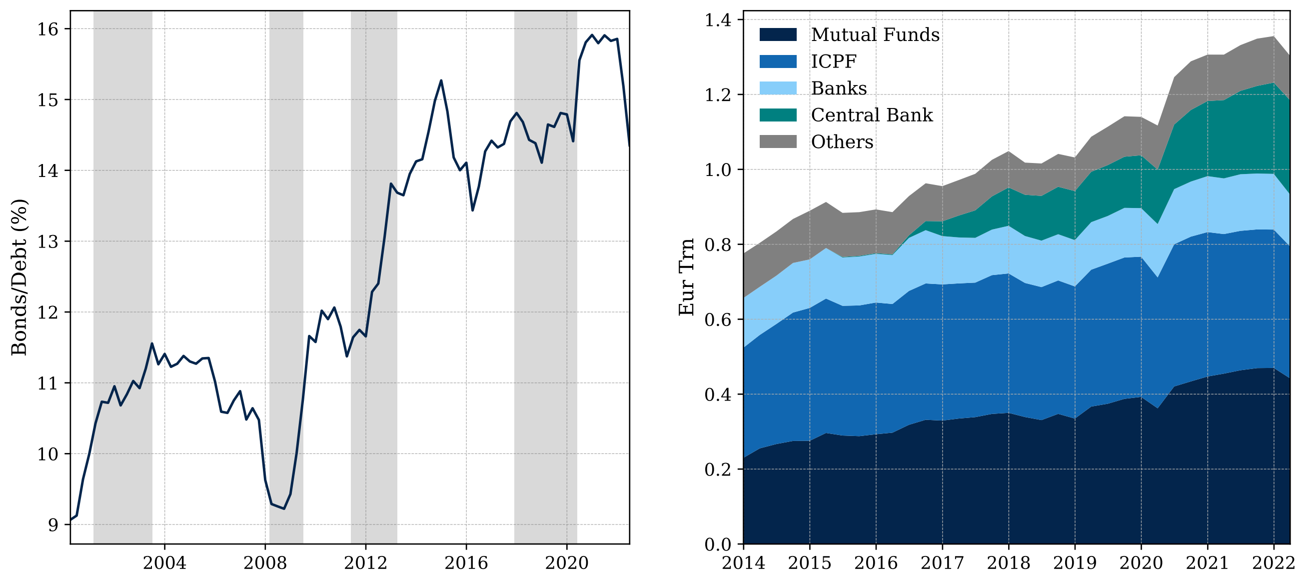
[3] We consider long-term, any loans or bonds with a maturity greater than one year, in accordance with the European System of Account (ESA) 2010 definition.

[4] Note that throughout the paper, we use the term ECB to represent the whole Eurosystem. Large parts of the central bank asset portfolio in the Euro area are held by the National Central Banks that form the Eurosystem along with the ECB.

Figure 1: Euro area non-financial corporate bonds

(a) NFC Corporate Bonds

(b) NFC - Holdings by Sector



Note: Figure 1a shows the total amount of bonds issued by Euro area non-financial corporations as a share of total non-financial corporations' debt. Figure 1b splits the total amount of bonds issued by Euro area non-financial corporations by holding sector: mutual funds, insurance corporations and pension funds (ICPF), banks, central bank, and others. Source: Quarterly Sector Account.

2.1 Data

In order to study the effects of monetary policy shocks on corporate bonds and on the balance sheets of financial intermediaries, we combine a number of different data sets.

2.1.1 Holdings

We compute the shares of bonds held by different intermediaries by leveraging granular information from the ECB Securities Holding Statistics (SHS). SHS is a security-level portfolio holdings database of all euro-area investors. The securities are uniquely identified by an International Securities Identification Number. The dataset includes information on government and corporate bonds, equities, and mutual fund shares. Data are reported at a quarterly frequency, and our sample covers 2013Q4 to 2021Q4. Securities Holding Statistics reports portfolio holdings by country of domicile and investor sector. We aggregate data for all Euro area countries and only split by investor sector. We use data for monetary financial institutions (which we refer to as banks), insurance companies and pension funds (ICPF), and mutual funds.

2.1.2 Information on Financial Assets

We collect data from Markit iBoxx. The dataset provides detailed information on the universe of bonds used in their index. We only include bonds denominated in euros. The data are available at a daily frequency and include bond bid price, ask price, accrued interest, yield to maturity, duration, and ratings. We also construct a set of additional measures. We compute a measure of illiquidity defined as the autocorrelation in returns in a given quarter, following the methodology of Bai et al. (2019). We use the ECB CSDB (Central Securities Database) to collect ratings by three agencies: Fitch Ratings, Moody's and Standard & Poor's (S&P).

For each bond, we also compute the spread with respect to a maturity-matched default-free interest rate. To this end, we use data on different swap instruments. From 2002 to 2006, we used Euribor with a maturity of up to 1 year and Swap rates written on 6m Euribor for longer maturities. We use OIS EONIA rates from 2007 to 2021. Finally, from 2021 onward, we use the OIS-€STR rates. We use the 1m to 12m maturity, the 1y to 10y maturity, 12y, 15y, 20y, 25y, and 30y. We interpolate swap yield using a cubic spline.

We use data from the Euro Area Monetary Policy Event-Study Database (EA-MPD), developed by Altavilla et al. (2019), to measure the high-frequency intraday movement in OIS rates around ECB announcements.

3. Monetary Policy Shocks

In order to systematically investigate monetary policy transmission to the cross-section of corporate bonds, we construct two monetary policy shocks series: i) a new credit spread monetary policy shock and ii) a term spread monetary policy shock. We measure our monetary policy shocks in a short window around all ECB scheduled Governing Council announcements from 2014 to 2021.

The term spread monetary policy shock is the change in term spread (defined as the 10-year OIS minus the 2-year OIS) in an intraday window around the ECB announcements. The credit spread monetary policy shock is the change in corporate bond credit spread in a two-day window around the ECB announcement: from the day before the announcement to the day after. It is standard practice to measure the effects of monetary policy on corporate bonds in a larger window to reduce the effects of stale pricing or low liquidity. We construct the credit spread component by decomposing the market corporate bond yield into an interest rate component and a credit spread component:

$$\underbrace{Y_t}_{\substack{\text{Market Corporate} \\ \text{Yield}}} = \sum_i w_{i,t} \times y_{i,t} = \underbrace{\sum_i w_{i,t} \times \iota_{i,t}}_{\substack{\text{Interest Rate} \\ \text{Component}}} + \underbrace{\sum_i w_{i,t} \times ys_{i,t}}_{\substack{\text{Credit Spread} \\ \text{Component}}}, \tag{1}$$

where $y_{i,t}$ is the yield-to-maturity of bond i at time t, and $w_{i,t}$ is the notional outstanding amount of bond i as a share of the total outstanding amount of all bonds in the sample, $\iota_{i,t}$ is the swap yield with maturity equal to the maturity of bond i while $ys_{i,t}$ is the spread of corporate bond i. The interest rate component measures the variation of credit yield due to variation in default-free rates: a combination of future expected short-term interest rates and term-premium. We use the variation in the second component, the credit spread component, as our measure of credit spread monetary policy shocks:

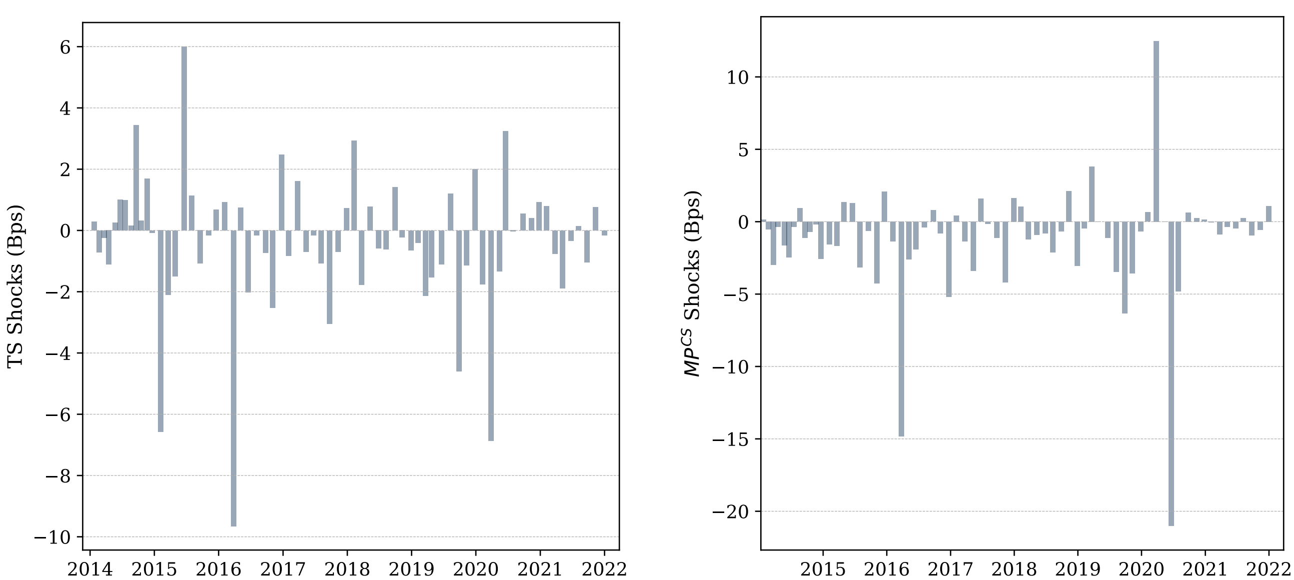
$$MP_t^{CS} = \sum_i w_{i,t} \times \Delta ys_{i,t}, \tag{2}$$

where we define $\Delta ys_{i,t} = (ys_{i,t+1} - ys_{i,t-1})$, as the change around monetary policy announcement t.[5] Figure 2 plot the time series of the two shocks.

Figure 2: Monetary Policy Shocks

(a) Term Spread (TS) Shocks

(b) Credit Spread (CS) Shocks



Note: The figure shows our two monetary policy shocks. Figure 2a plots the term-spread monetary policy shock, defined as the change in term spread (10-year OIS minus the 2-year OIS), in the intraday window around the ECB announcements. Figure 2b plots the credit spread monetary policy shocks, the change in Euro-denominated investment grade non-financial corporate bond credit spread in a two-day window around the ECB announcement (from the day before the announcement to the day after). The sample runs from January 2014 through December 2021.

[5] We drop observations where $ys_{i,t}$ is smaller than 300bps or higher than 3000bps. We also winsorize $\Delta ys_{i,t}$ at the bottom 5% and the top 5%; as we are using a large cross-section of corporate bond yields, we want to capture the overall variation in credit spreads, and therefore we want to limit the effects of idiosyncratic corporate bond variation on our monetary policy shock.

3.1 Credit Spread Monetary Policy Shocks and ECB Corporate Purchases

The credit spread shock captures the direct effect of ECB policies on the corporate bond market. On March 10, 2016, the ECB announced its decision to extend its asset purchase programme to euro-denominated investment-grade corporate bonds issued by non-financial corporations established in the Euro area (the Corporate Sector Purchase Programme, CSPP). On the day of the announcement, we observe a sharp contraction of market corporate bond yield, with yields continuing to fall in the period after the announcement (see Figure 3a). The figure clearly shows that the CSPP announcement successfully lowered bond yields.

In 2020, the Covid crisis prompted the ECB to increase the size of its interventions by extending its asset purchase programme. The spike in the number of Covid cases in Eurozone countries and the uncertainty related to the economic outlook led to a sudden adverse repricing of financial assets. Amid the turbulence in the financial market, after the scheduled governing council of March 12, 2020, ECB President Christine Lagarde announced a series of measures to support the economy. The ECB announced to "add a temporary envelope of additional net asset purchases of €120 billion until the end of the year, ensuring a strong contribution from the private sector purchase programmes".[6] After the announcement, bond market prices plunged as financial markets considered the ECB inadequate to face the magnitude of the shocks.

On March 18, 2020, outside a regularly scheduled governing council meeting, the ECB announced its decision to massively increase the size of its interventions through pandemic emergency purchase programme (PEPP), with an initial envelope of €750bn. The two vertical lines in Figure 3b denote the dates of these two events. The figure exhibits the rise in yields in March 2020, which was exacerbated by the ECB meeting. The PEPP announcement stopped the fierce rise in bond yields and led to a sudden reversal and a reduction in funding costs. Overall, Figure 3 shows the powerful effects of ECB corporate purchases on corporate bond yields.[7]

The transmission of ECB monetary policy can work either through a reduction in the interest rate component of corporate bond yields or via compression of the credit risk component. In order to shed light on the transmission mechanism, we use the decomposition described in Equation 1, to disentangle the variation in the two components around ECB announcements. Following the CSPP announcement, the net interest rate contribution is null. We instead observe a sizeable reduction in credit spread, which is driving most of the variation.

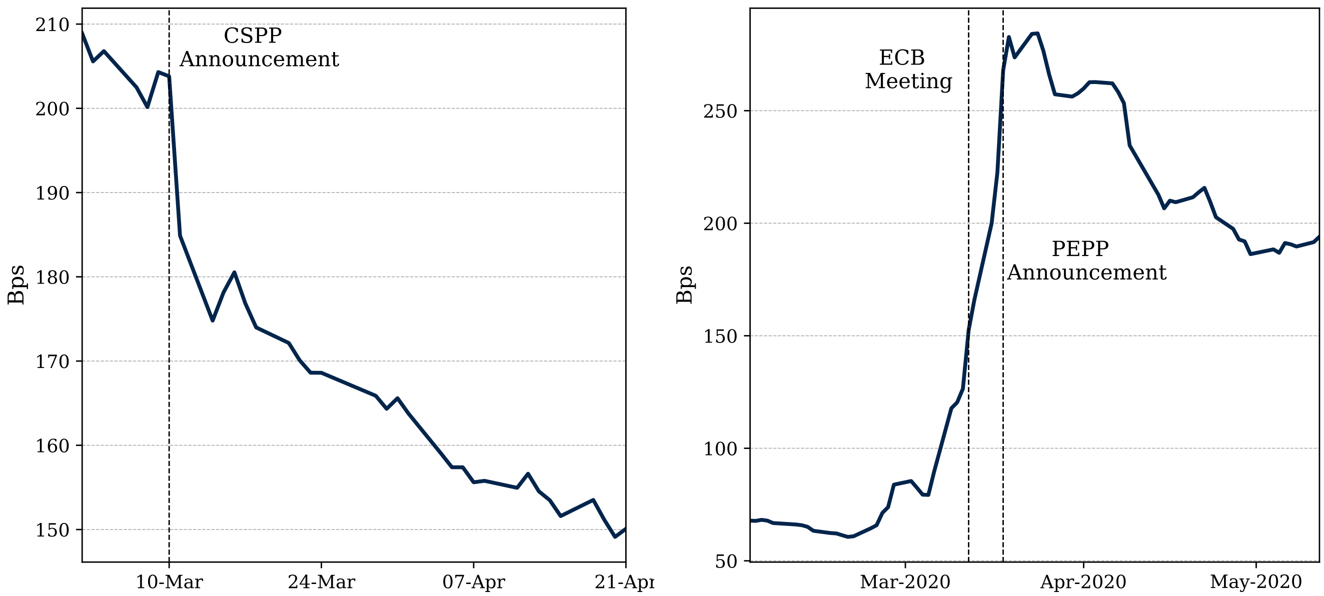
Figure 4b also shows that the relative contribution of the credit risk component dwarfed the

[6] ECB Press Conference, March 12, 2020

[7] The two policy packages did not only affect prices; the period following the announcements also saw an increase in the volume of bond issuance by euro area non-financial corporations, as shown in Figure 20, in Appendix B. Several papers in the literature (see Abidi and Miquel-Flores (2018); Grosse-Rueschkamp et al. (2019); Zaghini (2020); De Santis et al. (2018); Todorov (2020); De Santis and Zaghini (2021)) further demonstrated the causal link between CSPP announcement and the effects on bond yields and bond volumes.

Figure 3: Announcements of CSPP and PEPP

(a) CSPP Announcement (b) PEPP Announcement



Note: The figure shows the evolution of the value-weighted Euro area non-financial corporations bond yields. Figure 3a shows the evolution around the Corporate Sector Purchase Programme (CSPP) announcement on March 10, 2016. Figure 3b shows the evolution around the Pandemic Emergency Purchase Programme (PEPP) announcement on March 20, 2020. Source: Markit iBoxx.

interest rate component at the launch of the PEPP programme. As expected, the rise in bond yields at the onset of the Covid crisis was entirely driven by a surge in credit spread. The timely interventions of the ECB halted the spike in credit spread and led to a gradual reduction in yields.

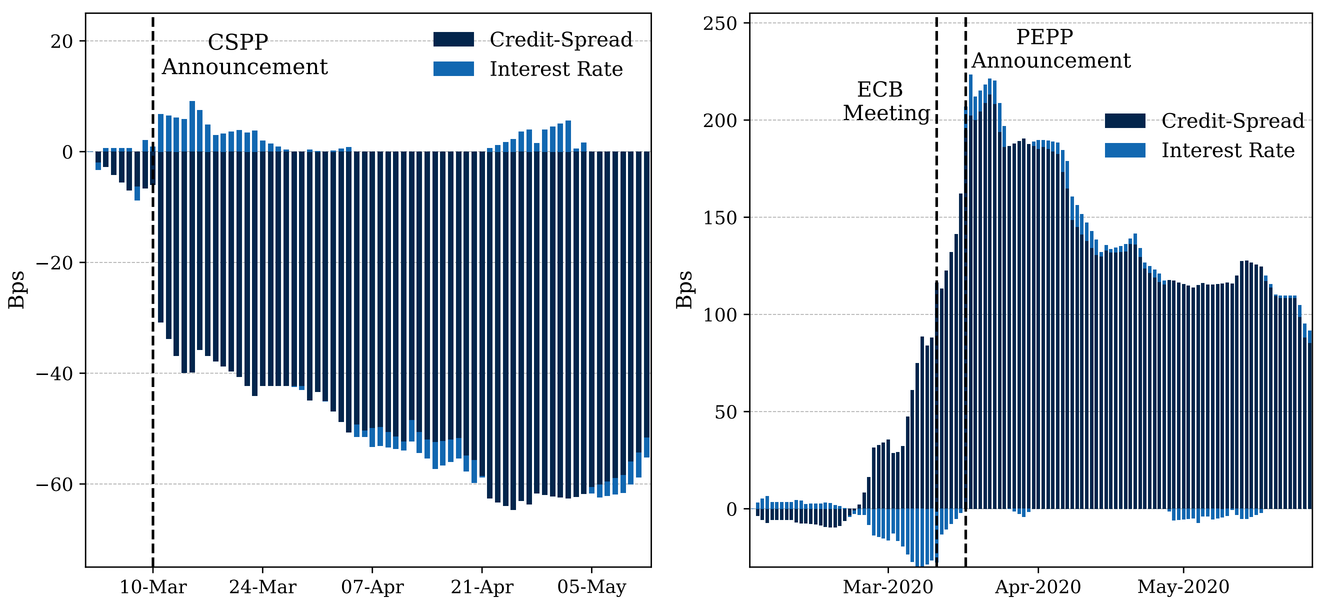
The two examples shows the importance of ECB corporate sector purchases for credit spreads. Figure 5 plots the time series of credit spread shocks from 2014 through 2021. Each bar in the figure corresponds to a scheduled ECB governing council meeting: a negative number means credit spreads fall on that meeting. In the figure, we show that the most significant shocks (highlighted in dark blue) all correspond to announcements regarding corporate sector purchases. In March 2016, the ECB launched the CSPP programme, and in December 2016 the ECB extended the duration of the APP programme. In December 2019, the ECB re-started the APP programme after its termination in December 2018. In March 2020, the ECB announced its measure to fight the turmoil in the market due to the Covid Crisis. Finally, in June 2020, the ECB extended the PEPP in terms of the amount of purchases (increasing the envelope for PEPP by €600 billion to a total of €1,350 billion) as well in terms of the duration of the programme.

We also show that the credit spread monetary policy shocks are poorly explained by monetary policy shocks estimated using OIS rates. The total variance explained by all shocks is roughly zero (see Table I). This analysis is further confirmed in Section E.1 where we conduct a variance decomposition of the variation in corporate bond yields around ECB announcement and demon-

Figure 4: Decomposition of CSPP and PEPP announcement

(a) Decomposition: CSPP Announcement

(b) Decomposition: PEPP Announcement



Note: The figure shows the decomposition of bond yields around ECB CSPP and PEPP announcement. We decompose the market corporate bond yield into an interest rate component and a credit spread component. The figure plots the individual contribution of the two components to the observed variation the overall corporate bond market yields. Source: Markit iBoxx.

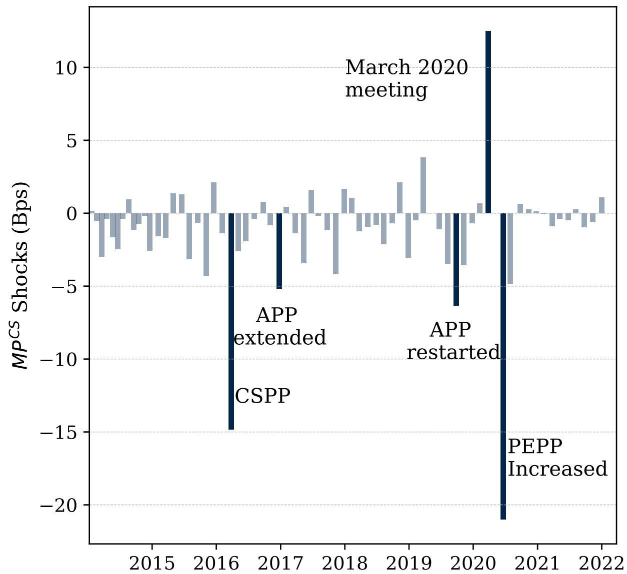
strate the relevance of the credit spread component. Our analysis shows the importance of using our new credit spread monetary policy shock to study the effects of ECB policies on the corporate bond market.

3.2 Term Spread Monetary Policy Shocks and ECB Government Bond Purchases

This section discusses the main drivers of our term spread monetary policy shock. The term spread monetary policy shock is highly correlated with the QE-OIS[8] shocks developed by Altavilla et al. (2019) based on the Euro OIS curve based on the methodology of Swanson (2021). The two shocks have a correlation of 0.7 in our sample (see Table II). The OIS-QE shock was developed to capture the effects of government bond purchases. Consistently, We find that the two most significant QE-OIS shocks correspond to January 2015 and December 2015. In January 2015, the ECB announced its government sector purchase programme (PSPP). In December 2015, markets expected a significant increase in the size of the PSPP programme. The package announced was

[8]We call the shocks QE-OIS as it captures the effect of quantitative easing through changes in the OIS rates. Our credit spread monetary policy shock also captures changes in QE (as corporate sector purchases are also a type of QE), using corporate sector credit spreads.

Figure 5: Time Series of Credit Spread Monetary Policy Shocks



Note: The figure shows the measured credit spread shocks MP^{CS} on ECB announcements from January 2014 through December 2021. We identify the largest shocks. The first coincides with the announcement of the Corporate Sector Purchase Programme (CSPP), the second and third with two announcements related to the Asset Purchase Programme (APP), the fourth with the March 2020 where the ECB dicussed the policy package after the Covid outbreak, the fifth coincides with the ECB extension of Pandemic Emergency Purchase Programme (PEPP). Source: Markit iBoxx.

Table I: Shocks and Various Interest Rate Shocks

	(1)	(2)	(3)	(4)
	MP^{CS}	MP^{CS}	MP^{CS}	MP^{CS}
	b/se	b/se	b/se	b/se
MP^{TS}	-0.010			0.052
	(0.49)			(1.34)
QE-OIS		-0.127		-0.183
		(0.43)		(2.50)
OIS 2Y			-0.060	-0.006
			(0.25)	(0.88)
Observations	80	80	80	80
R-squared	0.000	0.002	0.002	0.002

Note: The table shows the results from three regression estimates. We regress the credit spread monetary policy shocks on (i) the term spread shocks, (ii) the QE shocks developed by Altavilla et al. (2019) based on OIS rates and (iii) the change in the two year OIS around ECB announcement, a standard measure of monetary policy shock and (iv) all shocks together. The sample runs from 2014 through 2021.

below market expectations and led to a sharp increase in interest rates (a positive QE-OIS shock).

The term spread monetary policy shock and credit spread monetary policy shocks have a low correlation. In the following sections, we separately study the effect of the two shocks on the corporate bond market and the balance sheet of different intermediaries.

Table II: Shocks Correlation

	MP^{CS}	MP^{TS}	IR	Stoxx 50	QE-OIS	OIS 2Y
MP^{CS}	1.00	-0.01	0.03	-0.39	-0.01	-0.01
MP^{TS}	-0.01	1.00	-0.03	0.13	0.70	-0.29
IR	0.03	-0.03	1.00	-0.58	0.53	0.72
Stoxx 50	-0.39	0.13	-0.58	1.00	-0.27	-0.54
QE-OIS	-0.01	0.70	0.53	-0.27	1.00	0.47
OIS 2Y	-0.01	-0.29	0.72	-0.54	0.47	1.00

Note: The table shows the correlation for different shocks: our credit spread monetary policy shocks, our term spread shocks, the total variation in the interest rate component of corporate bonds around ECB announcements, the variation in the Euro Stoxx 50 around ECB announcement, the QE shocks developed by Altavilla et al. (2019) based on OIS rates and the change in the two year OIS around ECB announcement. The sample runs from 2014 through 2021.

4. Heterogeneous Response to Monetary Policy Shocks

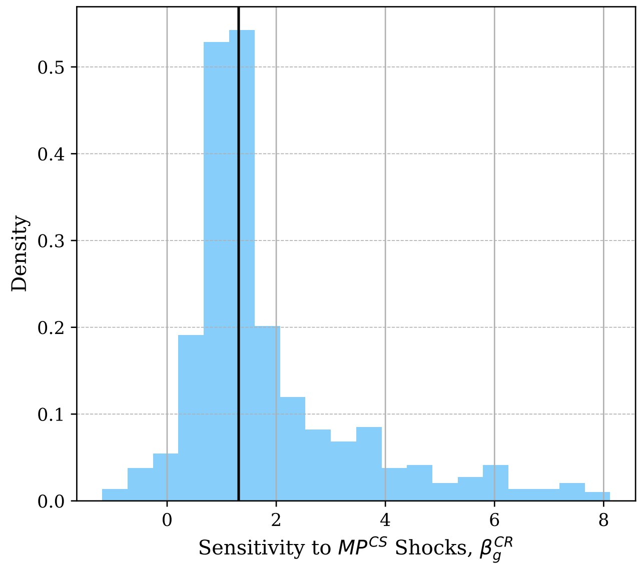
4.1 Corporate Bonds and Credit Spread Shocks

In this section, we estimate the cross-section of the sensitivity of corporate bonds to our credit spread monetary policy shock. We show how different bonds are affected by monetary policy shocks and discuss the relationship between the investor base composition of the bonds and the sensitivity of different bonds to the shocks.

There are several challenges in evaluating the response of corporate bonds to monetary policy shocks. First, bonds have limited maturity, and this limits their sample. Second, bond characteristics change over time: a bond mechanically changes maturity (or duration) as time goes by; the riskiness of the firm also varies over time. Third, corporate bonds exhibit a significant degree of idiosyncratic risk, which can confound our estimates. To circumvent these issues, we exploit the panel dimension of our corporate bond price database. We use a set of bond characteristics (maturity, ratings, sector) to cluster bonds into different groups.[9] Our final sample includes a

[9] We only use Euro-denominated corporate bonds. To have a larger sample, we use corporate bonds issued by non-financial corporations and by captive institutions. We include bonds with ratings ranging from AAA to B. We sample bonds according to maturity by dividing them into ten equally sized groups (maturity deciles). We use the average rating average of Fitch Ratings, Moody's, and Standard & Poor's (S&P) as well as the worst rating of the three rating agencies. Finally, we use sector according to the definition of Markit-iBoxx. We only consider groups with more than 20 observations

Figure 6: Distribution of Sensitivities to MP^{CS}



Note: The figure shows the distribution estimated bond sensitivity to MP^{CS} for different groups of corporate bonds, as estimated in Equation 3. We use a set of bond characteristics (maturity, ratings, sector) to cluster bonds into different groups. The vertical line is the median estimate. The sample runs from 2013Q4 to 2021Q4. Source: Markit iBoxx.

total of 539 groups: each group is a combination of maturity-rating-sector.

We then evaluate the sensitivity of the yield spread of each of these groups to our MP^{CS} shocks. We run a battery of panel regressions:

$$\Delta ys_{i,t}^{g} = \gamma_i + \beta_g^{CS} MP_t^{CS} + \varepsilon_{i,t}^{g}, \tag{3}$$

where $\Delta ys_{i,t}^{g}$ is the change in yield of corporate bond i of the group g at time t, measured using the 2-day change around each ECB announcement.[10] γ_i is a bond fixed effect.[11] A time t corresponds to each of the ECB announcements in our sample. We hence run a total of 539 panel regression (one for each group), where each individual observation is a combination of bond-time. This results in a total of 539 estimated β_{CS}^{g}. Figure 6 plots the distribution of sensitivity to our credit spread monetary policy shock MP^{CS}, illustrating the dispersion in β_g^{CS} estimates. The median sensitivity is around 1.2 (the black vertical line).

We now combine our corporate bond sensitivity results with asset holdings' data. For each group, exploiting the granular information of the ECB SHS database, we compute the holdings by two groups of investors: insurance corporations and pension funds (ICPF) and mutual funds. We pool data across the whole sample: for each group, we compute the share held by the different

[10] As we are comparing different corporate bonds, we allow for a slightly longer window to reduce the heterogeneous differences due to liquidity.

[11] We use a bond fixed effect to reduce the noise due to idiosyncratic factors.

intermediaries at each t and average across the entire sample. We then match the holdings for each group g with the estimated β^g_{CS}.

Figure 7 plots the results: each dot corresponds to a group. Figure 7a reports on the x-axis the estimated β^g_{CS} and on the y-axis the holding share (in percentage) by insurance corporations and pension funds (ICPF) for each group. The plot clearly shows a negative correlation between insurance and pension fund holdings and the sensitivity of bonds to MP^{CS} shocks. ICPFs hold more of the least responsive bonds (low β^g_{CS}) and less of the most responsive bonds (high β^g_{CS}). By contrast, Figure 7b plots the equivalent estimates for mutual funds. The figure shows a positive correlation between mutual fund holdings and the bond sensitivity to CR shocks. In this case, mutual funds hold less of the least responsive bonds and more of the most responsive bonds.

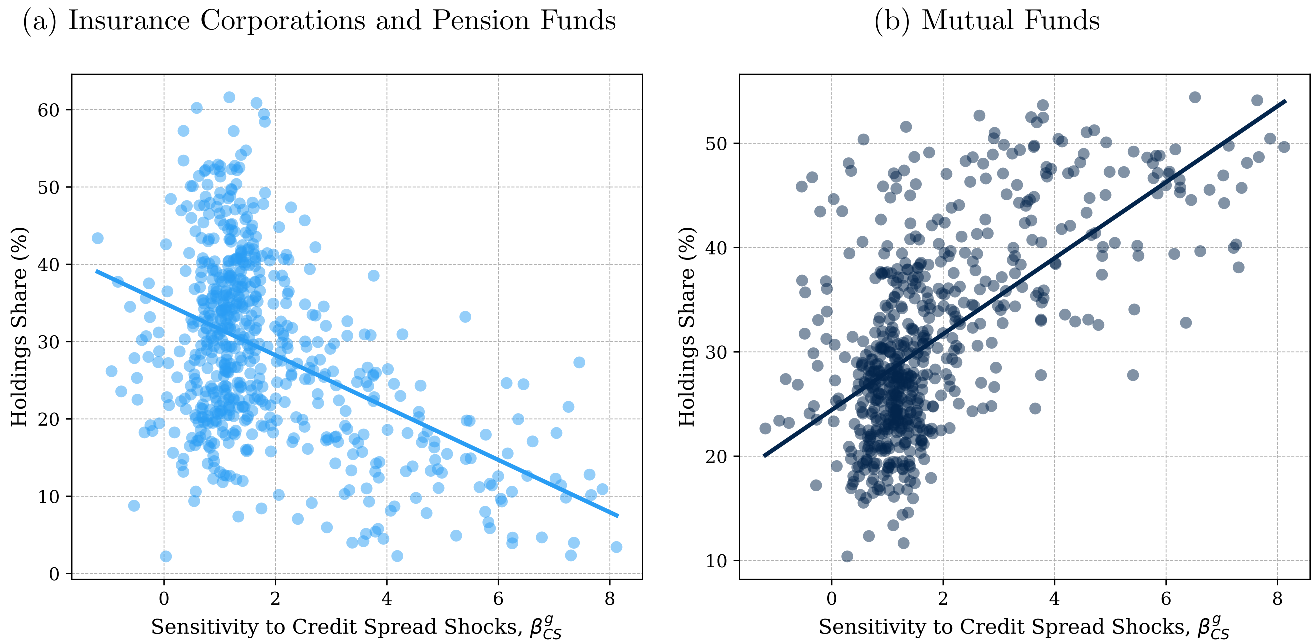
To sum up, Figure 7 shows a striking correlation between holdings by different intermediaries and the sensitivity of corporate bonds to our credit spread monetary policy shocks. Understanding the nature of this correlation is vital to learn how monetary policy shocks transmit to the cross-section of corporate bonds and how the transmission interacts with heterogeneous intermediaries' balance sheets. In section 4.1.1 we document that this heterogeneity in responses primarily reflects bond characteristics, rather than the investor base composition for a given bond, implying that intermediary sectors systematically select into different types of assets.

4.1.1 Holding Structure and Sensitivity to Credit Spread Shocks

Koijen et al. 2021 estimates the weighted average demand elasticity across investors for Euro area government bonds. The demand for each intermediary sector is based on characteristics of the bonds that reflect exposure to risk factors. Similarly, Bretscher et al. (2021) estimates the elasticity for corporate bonds based on characteristics for the US. In this approach, the aggregate elasticity is a sufficient statistic to estimate the effects of ECB purchases on the prices of bonds. The characteristics of the bonds then explain the cross-sectional effects of monetary policy shocks on different bonds. However, in a segmented market model, it is the demand curve of individual intermediaries in each segment that matters. Therefore, even if two bonds are nearly identical (i.e., similar characteristics), if the investor composition of the market is different, the price response may be significantly different. In this case, the characteristics of the bonds and the demand elasticity of investors are not enough to capture the cross-sectional effects of monetary policy. It is instead key to know the investor composition of each corporate bond. This mechanism can also explain the correlation we uncovered between price response to monetary policy shocks and intermediaries' holdings. Consistent with this hypothesis, recent literature has demonstrated that the investor base composition is an essential determinant of bond price dynamics during a recession. Coppola 2021 shows that the holding structure of the bond has significant effects on the transmission of credit crunches during a crisis to corporate bond yields.[12] Within our context,

[12]In Appendix D we show similar results using ECB data for the Covid crisis.

Figure 7: Holding shares and Bond Sensitivity to MP^{CS} Shocks



Note: The figure plots on the x-axis the estimated β^g_{CS} from Equation 3 (i.e., the sensitivity of each bond group to our credit spread monetary policy shock, M^{CS}) and on the y-axis the holding share (in percentage) for each group by insurance corporations and pension funds (Figure 7a) and mutual funds (Figure 7b). The shares are computed as the average shares across the full sample for each group. The sample runs from 2014 through 2021. Source: Markit iBoxx and ECB SHS.

bonds held by mutual funds may react differently to shocks because they are held by mutual funds. For example, a monetary policy shock can lead to inflows into the mutual fund sector that add price pressure to the bonds held by mutual funds.

We use the methodology developed by Coppola 2021 to try to disentangle the effects of individual intermediaries on corporate bonds. We use data on holdings by ICPF (insurance and pension funds) and mutual funds and test the relevance of the holding structure on the transmission of MP^{CS} shocks to bond yield changes. We use the information on bond characteristics to dissect the driver of heterogeneity. Controlling for bond characteristics, we can exploit heterogeneity in the holding structure of bonds (the share held by different intermediaries) to understand the role of different intermediaries for transmission.

We run the panel regression:

$$\Delta ys_{i,t} = \gamma_i + \beta^{CS} MP_t^{CS} + \beta^M \theta_{M,i,t} \times MP_t^{CS} + \beta^L \theta_{L,i,t} \times MP_t^{CS} + \text{Interacted Fixed Effects}$$
$$+ \eta^M \theta_{M,i,t} + \eta^L \theta_{L,i,t} + \varepsilon_{i,t}, \tag{4}$$

where $\Delta ys_{i,t}$ is the two-day change in spread of bond i around announcement t, $\theta_{M,i,t}$ are the shares of bond i held by mutual funds at time t, $\theta_{L,i,t}$ are the shares of bond i held by levered intermediaries (insurance companies and pension funds) at time t. All fixed effects, excluding the bond fixed effects, are interacted with a time fixed effect. Table IV use the following fixed effects: duration[13], issuer country, average rating, worst rating, issuer sector, issuer company. Table IV uses the following fixed effects: credit spread, bid-ask spread and illiquidity. We use information pre-announcement.

We run the regression for the sample 2014-2021 and restrict the sample to investment-grade non-financial corporate bonds. Table III reports the results. The coefficient of interest is β^L and β^M: the marginal effects of bond holdings on the response of bond yields to monetary policy. Going from column (1) to column (7), we are increasing the number of controls.

We then find that once we account for characteristics, there are minor differences in the sensitivity of bonds to monetary policy shocks. Figure 8 displays how including fixed effects on characteristics reduce the difference between the two coefficients for each of the model detailed in Table III, suggesting the characteristics of the bond rather than the holders are the main drivers of the different sensitivity to monetary policy shocks.

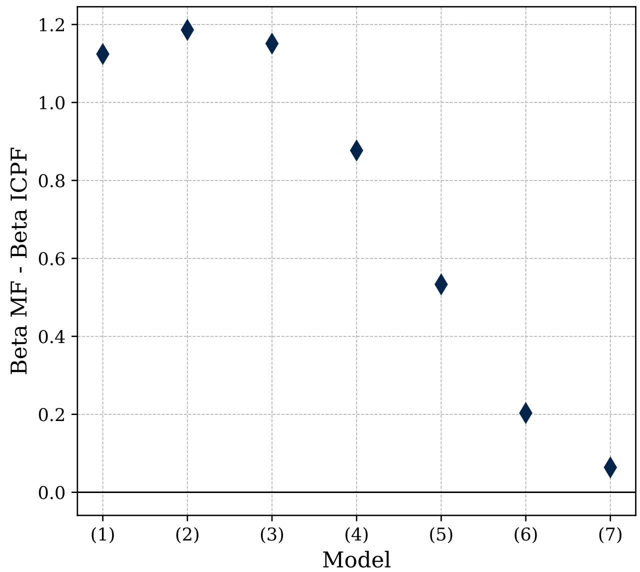
Table III: Holdings and Sensitivity to MP^{CS} shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Δ ys	Δ ys	Δ ys	Δ ys	Δ ys	Δ ys	Δ ys
	b/se	b/se	b/se	b/se	b/se	b/se	b/se
MP^{CS} x θ_L	0.053	0.052	0.077	0.158	0.155	0.079	-0.028
	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)
MP^{CS} x θ_M	1.178	1.238	1.228	1.035	0.688	0.282	0.036
	(0.11)	(0.11)	(0.12)	(0.12)	(0.12)	(0.11)	(0.05)
Levels	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	39870	39854	39407	38456	36901	30927	25216
Adj. R-squared	0.619	0.647	0.664	0.701	0.754	0.852	0.943
FE	ISIN	ISIN	ISIN	ISIN	ISIN	ISIN	ISIN
Interacted FE							
Duration	No	Yes	Yes	Yes	Yes	Yes	Yes
Country	No	No	Yes	Yes	Yes	Yes	Yes
Rating	No	No	No	Yes	Yes	Yes	Yes
Rating Worst	No	No	No	No	Yes	Yes	Yes
Liquidity	No	No	No	No	No	No	No
Bid-ask	No	No	No	No	No	No	No
Sector	No	No	No	No	No	Yes	Yes
Issuer	No	No	No	No	No	No	Yes

Note: The table shows the results of Equation 4. We run the regression for the sample 2014-2021 and restrict the sample to investment-grade non-financial corporate bonds. We use a different set of controls: duration (a dummy for each duration group: 0y-1y, 1y-3y, 3y-5y, 5y-8y, 8y+), issuer country, average rating, worst rating, bid-ask spread quintile, liquidity quintile, issuer sector, issuer company. All fixed effects, excluding the bond fixed effects, are interacted with a time fixed effect. Source: Markit iBoxx and ECB SHSs.

[13] We use a dummy for each duration group: 0y-1y, 1y-3y, 3y-5y, 5y-8y, 8y+.

Figure 8: Levered Institutions vs Mutual Funds: Difference between sensitivity



Note: The figure shows the difference between the estimated β^M and β^L in Equation 4 for a difference set of controls (i.e., the marginal effects of intermediary holdings on the sensitivity of bonds to our credit spread monetary policy shock, MP^{CS}). The x-axis numbering corresponds to the model estimated in each column of Table III. Each model use a different set of bond characteristics fixed-effects.

The sensitivity of different bonds is likely to be driven by their exposure to credit risk and hence to different policies. We now use Equation 4 but use as controls a different measure of credit risk. We use the credit spreads, before the announcement. This measure should reflect a large set of observable characteristics that may contribute to the perceived riskiness of a bond (e.g., the rating, the sector, the country, and the liquidity). Moreover, a company may receive different credit ratings from rating agencies (Fitch Ratings, Moody's, and Standard & Poor's (S&P)). We hence sample bonds according to credit spread decile (where the 1$^{\text{st}}$ decile are credit-safest bonds while the 10$^{\text{th}}$ are the credit-riskiest bonds). Column (2) in Table IV shows that if we just control for credit spread, the differential effects of bonds held by mutual funds vanish (or even switch sign). This shows that bonds with similar risk exposure have the same response, whether they are held by mutual funds or other intermediaries. This also shows that only controlling for rating is not enough to control for the riskiness of the bond. An alternative story is that mutual funds and insurance companies and pension funds hold bonds with different liquidity and this is causing the differential effect. Column (3) and (4) in Table IV use two different measures of liquidity. We either use bid-ask spread decile (we divide bonds into decile based on their bid-ask spread as to keep the results of the table comparable) or the illiquidity deciles, based on the measure of Bai, Bali, and Wen (2019). The table shows that liquidity only accounts for a small fraction of the differential effect. We then conclude that the main driver of policy transmission is the exposure of bonds to credit risk.

The results of Table IV inform the nature of the transmission of the shocks. We conclude that the differential credit risk of bonds is sufficient statistics for the cross-sectional effects of the shocks on the cross-section of corporate bond yields. The results have also several implications. Different Euro area countries are characterized by different financial industries. We could then imagine that the transmission to bonds with similar credit risk but issued by different countries would have different price reactions because the shares of intermediaries holding them are different. However, Table IV shows that this is not the case. Two corporate bonds with similar risk exposure exhibit similar price reactions.

Table IV: Holdings and Sensitivity to MP^{CS} shocks

	(1)	(2)	(3)	(4)
	Δ ys	Δ ys	Δ ys	Δ ys
	b/se	b/se	b/se	b/se
MP^{CS} x θ_L	0.053	-0.063	-0.300	0.177
	(0.12)	(0.03)	(0.14)	(0.03)
MP^{CS} x θ_M	1.178	-0.112	0.730	1.126
	(0.36)	(0.12)	(0.30)	(0.39)
Levels	Yes	Yes	Yes	Yes
Observations	39870	39869	39867	39868
Adj. R-squared	0.619	0.796	0.693	0.682
Fixed Effects	ISIN	ISIN	ISIN	ISIN
Interacted FE				
Credit Risk	No	Yes	No	No
Bid-ask	No	No	No	Yes
Illiquidity	No	No	Yes	No

Note: The table shows the results of Equation 4. We run the regression for the sample 2014-2021 and restrict the sample to investment-grade non-financial corporate bonds. We use a different set of controls: credit risk decile, liquidity decile, bid-ask decile. All fixed effects, excluding the bond fixed effects, are interacted with a time fixed effect. Source: Markit iBoxx and ECB SHSs.

4.2 Corporate Bonds and Term Spread Shocks

In Section 4.1 we discussed the heterogeneous effects of corporate bonds on our credit spread monetary policy shock. A natural question is whether the correlation between intermediary holdings and monetary policy holds for a different type of shock. To this end, in this section, we study the relationship between the cross-sectional effects of the term spread monetary policy shocks and intermediary holdings.

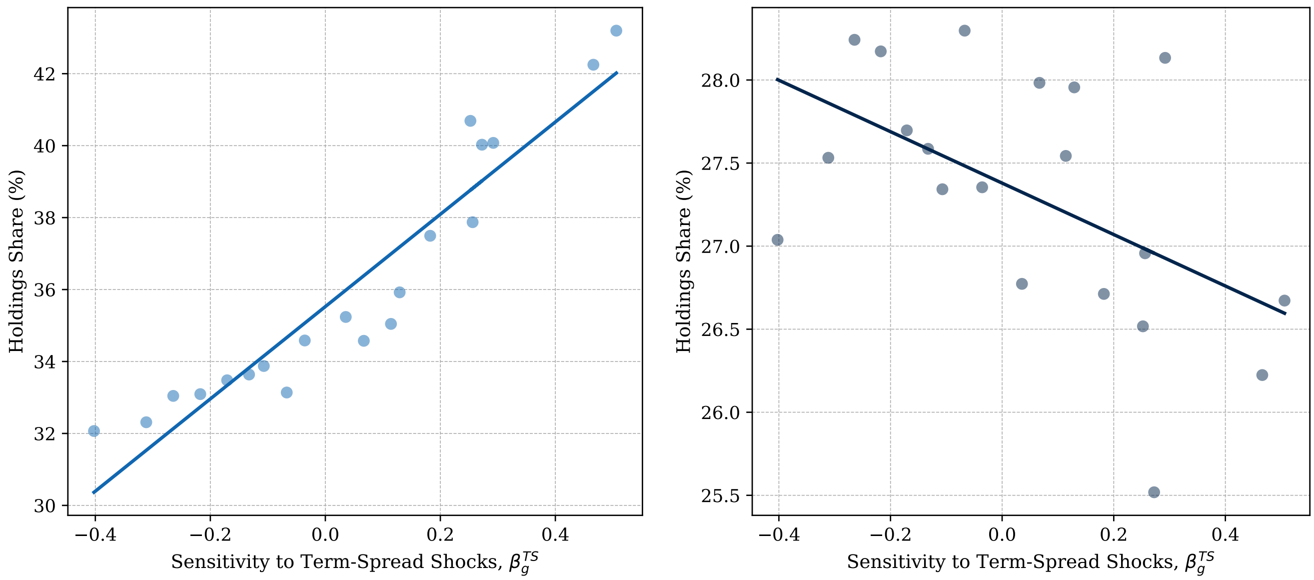
As the effects of the term spread shock on a credit spread are close to zero, we estimate the sensitivity of the interest rate component $\iota_{i,t}$ of the bond to the shocks. We run the following regression:

$$\Delta\iota^g_{i,t} = \gamma_i + \beta^{TS}_g MP^{TS}_t + \varepsilon^g_{i,t}, \tag{5}$$

Figure 9: Holding shares and Bond Sensitivity to TS Shocks

(a) Insurance Corporation and Pension Funds

(b) Mutual Funds



Note: The figure plots on the x-axis the estimated β_{TS}^{g} of Equation 5 and on the y-axis the holding share (in percentage) for each group by insurance corporations and pension funds (Figure 9a) and mutual funds (Figure 9b). The shares are computed as the average shares across the full sample for each group. Source: Markit iBoxx and ECB SHS.

where $\Delta\iota_{i,t}^{g}$ is the change in the credit risk-free component of bond i of group g at time t, measured using the change around each the ECB announcement. In this case, we can use the shorter one-day window as we are measuring the sensitivity of the OIS component of different bonds to the shocks. Moreover, bonds only differ in their maturity. We, therefore, split our sample into twenty maturity groups and estimate twenty β_g^{TS}. The results are reported in Figure 9.

Our results show a striking correlation between intermediary holdings and bond sensitivity to our term spread shocks. Insurance companies and pension funds hold larger shares of more responsive bonds (see Figure 9a). This result is antithetical to what we have found for the credit spread monetary policy shock. In section 4.1.1 we exploit that significant cross-sectional variation in corporate bond spreads to illustrate how bond sensitivity primarily depends on the characteristics of the bonds rather than the individual investor base composition. It is impossible to conduct an analogous exercise for the term spread shocks as the OIS component $\iota_{i,t}$ is common to all bonds with the same maturity.

5. A Model of the Bond Market

In section 4 we showed a stark correlation between intermediaries' bond holdings and the sensitivity to different monetary policy shocks. Our empirical results suggest that this difference is driven by how different intermediaries select into different bonds based on their characteristics. In order to rationalize these findings, we develop an intermediary asset pricing model with multiple risky assets. In section 5.1 we describe the environment, while in section 5.2 we show the main predictions of the model.

5.1 Environment and Equilibrium

5.1.1 Assets

Factors We exploit the factor structure in fixed-income securities to represent different agent portfolios in terms of simple factor portfolios. We focus on two orthogonal risk factors: interest rate risk (IR) and credit risk (CR). The two risk factors follow the dynamic:

$$f_{t+1}^{IR} = \rho f_t^{IR} + \varepsilon_{t+1}^{IR},$$

$$f_{t+1}^{CR} = \rho f_t^{CR} + \varepsilon_{t+1}^{CR},$$

$$\varepsilon^{IR} \sim N\left(0, \sigma_{IR}^2\right) \qquad \varepsilon^{C} \sim N\left(0, \sigma_{CR}^2\right),$$

where the two shocks are uncorrelated. Define $F_t = (f_t^{IR}, f_t^{CR})'$, the vector of the two factors.

There are two claims, whose payments depend on the realization of the two factors. The IR claim depends on the realization on f^{IR} while the CR claim depends on the realization of f^{CR}. The payments are:

$$\log d_{t+1}^{IR} = \alpha^{IR} + f_{t+1}^{IR}$$

$$\log d_{t+1}^{CR} = \alpha^{CR} + f_{t+1}^{C}.$$

The IR claim and CR claim, are in positive supply: $\Theta = (\theta^{IR}, \theta^{CR})'$.

We also have an additional instrument, which is the debt of the intermediary. The gross supply is also fixed to $\bar{\ell}$ and the payment is:

$$\log d_{t+1}^{\ell} = \alpha_{\ell} + \beta_{\ell}^{IR} f_{t+1}^{IR}.$$

The payment of the instrument is also exposed to interest rate risk.

5.1.2 Central bank

The central bank chooses the amount of risk-free debt b_t^{CB}, its price q_t^{CB} and the allocation to risky assets $X_{CB,t} = (x_{CB,t}^{IR}, x_{CB,t}^{CR})'$. The central bank budget constraint is:

$$(P_t' + D_t')X_{CB,t-1} - b_{t-1}^{CB} = P_t' X_{CB,t} - q_t b_t^{CB} + \Pi_t^{CB}. \tag{6}$$

where $P_t = (p_t^{IR}, p_t^{CR})'$ is the vector of prices, $D_t = (d_t^{IR}, d_t^{CR})'$ is the vector of payments from the two risky claims. Π_t^{CB} are the proceeds from the central bank portfolio. The proceeds are rebated to households: a share $1 - \varphi$ is redistributed to the bond investor, while a share φ is redistributed to the passive household. This implies that the taxes/rebates to the two household types are:

$$T^a = (1 - \varphi)\Pi_t,$$

$$T^p = \varphi \Pi_t,$$

where T^a are total taxes/rebates to the active households while T^p are total taxes/rebates to the passive households.

5.1.3 Asset Managers

The asset managers choose the allocation across risky claims $X_{M,t} = (x_{M,t}^{IR}, x_{M,t}^{CR})'$. They do not have the technology to borrow. They further choose the net payoff to its shareholder, π_t^M. π_t^M can be either positive (net-dividend payment or buyback) or negative (equity injection by the household). The asset manager budget constraint is defined as:

$$\pi_t^M + P_t' X_{M,t} \leq W_t^M, \tag{7}$$

where W_t^M is the initial wealth. The wealth evolution follows the equation:

$$W_{t+1}^M = (P_{t+1}' + D_{t+1}')X_{M,t}. \tag{8}$$

The asset managers maximizes the value of the firm,

$$V^M(W_t^M, F_t) = \max_{\pi_t^M, X_{M,t+1}} \pi_t^M + \mathbb{E}\left[M_{t+1}^a V^M(W_{t+1}^M, F_{t+1})\right]$$

subject to Equation 7-8, where M_{t+1}^a is the stochastic discount factor of the active households, the shareholder of the firm.

5.1.4 Levered Intermediaries

The levered intermediaries have initial net-wealth W_t^L. They choose their asset allocation across risky claims, $X_{L,t} = (x_{L,t}^{IR}, x_{L,t}^{CR})'$ and the net payoff to its shareholder, π_t^L. The intermediary takes the amount of central bank debt b_{t+1}^{CB}, their price q_t^{CB} as well as the amount of borrowing $\bar{\ell}$ as given.

Regulatory Framework The intermediary net-proceeds from the investment is:

$$\tilde{\pi}_{t+1}^L = D_{t+1}' X_t - \bar{\ell} d_{t+1}^{\ell}. \tag{9}$$

The intermediary faces a regulatory cost proportional to the variance of its net-proceeds. The total cost is:

$$\frac{\psi}{2} Var(\tilde{\pi}_{t+1}^L), \tag{10}$$

where ψ is the parameter that governs the severity of the regulatory cost. The intermediary also faces a collateral constraint:

$$P_t' \Omega X_t^L \leq \bar{\ell} p_t^{\ell} \tag{11}$$

where Ω is a diagonal matrix containing the collateral coefficients ω^{IR}, ω^{CR} of the two risky claims.

Intermediary Problem The intermediary budget constraint is defined as:

$$\pi_t^L + \frac{\psi}{2} Var(\tilde{\pi}_{t+1}^L) + P_t' X_{L,t} + q_t^{CB} b_t^{CB} - p_t^{\ell} \ell \leq W_t^L. \tag{12}$$

The wealth evolution follows the equation:

$$W_{t+1}^L = (P_{t+1}' + D_{t+1}') X_{L,t} - \ell (p_{t+1}^{\ell} + d_{t+1}^{\ell}) + b_t^{CB}. \tag{13}$$

The intermediary maximizes the value of the firm,

$$V^L(W_t^L, F_t) = \max_{\pi_t^L, X_{L,t}} \pi_t^L + \mathbb{E}\left[M_{t+1}^a V^L(W_{t+1}^L, Fs_{t+1}) \right] \tag{14}$$

subject to Equation 9-13, where M_{t+1}^a is the stochastic discount factor of the entrepreneur, the shareholder of the firm.

5.1.5 Active Investors

The active investors have Epstein-Zin Utility over consumption. They are the shareholders of the intermediaries. We also assume the active households receive a non-stochastic stream of income y. Their consumption is:

$$C_t^a + \leq y^a + \pi_t^L + \pi_t^M + T_t^a + \frac{\psi}{2} Var(\tilde{\pi}_{t+1}^L) \tag{15}$$

where C_t^a is consumption at time t, π_t^M is the net payout from the asset manager, π_t^L is the net payout from the levered intermediary, and T_t^a are taxes/rebate. We also assume that the regulatory cost of the levered intermediary, $\frac{\psi}{2} Var(\tilde{\pi}_{t+1}^L)$, is rebated to the intermediary shareholders.

The active household utility is:

$$V^a(F_t) = \left\{ (1-\beta) C_t^{a\,1-\frac{1}{\sigma_a}} + \beta_e E_t \left[V(F_{t+1})^{1-\gamma_a} \right]^{\frac{1-\frac{1}{\sigma_a}}{1-\gamma_a}} \right\}^{\frac{1}{1-\frac{1}{\sigma_a}}}, \tag{16}$$

subject to Equation 15. Further define the SDF of the active investors as:

$$M_{t+1}^a = \beta^a \left(\frac{V_{t+1}^a}{CE_t^a} \right)^{1/\sigma_e - \gamma_e} \left(\frac{C_{t+1}^a}{C_t^a} \right)^{-1/\sigma_e} \tag{17}$$

5.1.6 Passive Households

The passive has no access to the IR and CR assets. However, it can saves in the liabilities of the intermediary. We also assume the passive households receive a non-stochastic stream of income y^p. The budget constraint is therefore defined as:

$$C_t^p + p_t^\ell \ell_{p,t+1} \leq y + W_t^p + T_t^\omega, \tag{18}$$

where W_t^p is the wealth of the passive at time t, and T_t^ω are the total taxes and rebate. The wealth evolution of the passive is:

$$W_{t+1}^p = y^p + \ell_{p,t+1}(d_{t+1}^\ell + p_{t+1}^\ell) \tag{19}$$

The passive household solves the problem:

$$V^p(W_t^p, F_t) = \max_{C_t^p, \ell_{t+1}^p} \left\{ (1-\beta) C_t^{p\,1-\frac{1}{\sigma_p}} + \beta_p E_t \left[V(W_{t+1}^p, F_{t+1})^{1-\gamma_p} \right]^{\frac{1-\frac{1}{\sigma_p}}{1-\gamma_p}} \right\}^{\frac{1}{1-\frac{1}{\sigma_p}}} \tag{20}$$

subject to Equation 18 - 19. Further define the SDF of the passive household as:

$$M_{t+1}^p = \beta^p \left(\frac{V_{t+1}^p}{CE_t^p} \right)^{1/\sigma_p - \gamma_p} \left(\frac{C_{t+1}^p}{C_t^p} \right)^{-1/\sigma_p} \tag{21}$$

5.1.7 Equilibrium

After defining the asset space and the individual problems of each agent, we describe the equilibrium of the model.

Given a process for $\{F_t\}_0^\infty$ and a Central bank policy $\{X_{CB,t}, b_t^{CB}, q_t^{CB}\}_0^\infty$, the equilibrium is:

1. a path of prices $\{p_t^{IR}, p_t^{CR}, p_t^{\ell},\}_0^\infty$
2. consumption $\{C_t^p, C_t^a\}_0^\infty$
3. and allocations $\{X_{M,t}, X_{L,t}\}_0^\infty$

such that

1. the active households maximize their utility 16 subject to the budget constraint 15
2. the passive households maximize their utility 20 subject to the budget constraint 18
3. the asset managers maximize their utility subject to Equation 7-8
4. the levered intermediary maximize their utility subject to Equation 9-13
5. all markets clear:

$$x_{M,t}^{IR} + x_{L,t}^{IR} + x_{CB,t}^{IR} = \theta^{IR}$$

$$x_{M,t}^{CR} + x_{L,t}^{CR} + x_{CB,t}^{CR} = \theta^{CR}$$

$$\ell_t = \bar{\ell}$$

6. the good market clears:

$$C_t^a + C_t^p = \theta^{IR} d_t^{IR} + \theta^{CR} d_t^{CR} + y^p + y^a$$

5.1.8 Model Solution and Policy Experiment

We use the model to provide qualitative predictions. However, in order to better illustrate the mechanisms, we based our results on a calibrated set of parameters. We first solve the model for an economy where $\{X_{CB,t}, b_t^{CB}\}_{t=0}^\infty = 0$. We solve for a set of equilibrium prices and allocations $(\tilde{P}_t, \tilde{p}_t^{\ell}, \tilde{X}_t^L, \tilde{X}_t^M)$, for the value of shocks equal to 0: $f_t^{IR} = f_t^{CR} = 0$. We use these set of equilibrium prices and allocations to calibrate the parameters, as detailed in Section 5.1.9. We also discussed a set of predictions on allocations in Section 5.2.1 and on asset prices in Section 5.2.2. We then show the effects of central bank interventions by means of a counterfactual economy with time-invariant central bank's policy $\bar{X}^{CB}, \bar{b}^{CB}, \bar{q}^{CB}$.

5.1.9 Illustrative model parameters for numerical exercises

We describe the set of parameters used to illustrate the model's mechanism. We normalize the β^ℓ, the risk exposure of the levered intermediary debt to IR factor to 1. We set $\beta^a = 0.96$, targeting a real rate in the non-stochastic steady state of 4%.

The passive households are only pricing the debt of the levered intermediary. We set the β^p to 0.97, meaning that the passive households are slightly more patient than the active households. We assume that the passive households have log-utility; $\sigma_p = 1$, $\gamma_p = 1$. We set the coefficient that controls the tightness of the constraint to $\psi = 1$. The quadratic form of the regulatory cost implies that the multiplier on the collateral constraint scales with ψ. Due to this convenient scaling, we show that allocations and prices do not depend on ψ. We define: $\Omega = diag(\omega + \Delta, \omega)$, where Δ is the collateral advantage of interest rate risk holdings versus credit risk holdings. We set the value to 0.5; in a similar setting, Gertler and Karadi (2018) uses a value of 0.5 for Δ as the collateral advantage of government bonds on corporate bonds.

We then jointly calibrate: $\Theta, \gamma^a, \sigma^a, \bar{\ell}, \omega, \alpha, \sigma$ to match: (i) Risk-premium and volatility of IR and CR to 3% and 8%, (ii), market share of levered intermediaries = 50%, (iii) asset to liability ratio of levered intermediaries = 1.15. To simplify the exposition of results, we set the risk premia and volatility of IR claim and CR claim to be the same. Based on our estimates, the risk-premium on interest rate risk returns and credit risk returns ranges from 2% to 4%; we then calibrate the model to a value of 3%. Our estimates of the volatility are also between 6% and 12%. We calibrate the model to a value of 8%. In the corporate bond market, mutual funds and levered intermediaries (ICPFs) hold roughly similar shares. We, therefore, target bond shares of 50% for both asset managers and levered intermediaries. Based on a regulatory report from EIOPA, the asset-to-liability ratio of insurance companies in Europe is 115%, motivating our value of 1.15.

We calibrate the parameters jointly within pre-defined bounds.[14] We find the set of parameters to be: $\Theta = (1.7, 1.3)'$, $\gamma_a = 27.5$, $\sigma_a = 1.4$, $\bar{\ell} = 0.5$, $\omega = 0.16$, $\alpha = 0.4$, $\sigma = 0.2$.

5.2 Model Results

5.2.1 Asset Allocation

In this section we show how different intermediaries choose to exposed to different risk factors. Levered intermediaries choose to be more exposed to the interest rate risk factor while asset managers choose to be exposed to the credit risk factors.

We consider the allocations without central bank interventions and describe the allocation of the levered intermediary. Combining Equation 9 and 10, the total regulatory cost, at time t, as a

[14]We set the bounds for θ^{IR} and θ^{CR} to [0.5,2], for γ^a to [5, 30], for σ_a to [0.1,2], for $\bar{\ell}$ we set the bounds as shares of θ^{IR} to [0.1, 0.95], for α and σ to [0.01,0.5].

function of $X_{L,t}$ is:

$$\frac{\psi}{2}\left(X'_{L,t}\Sigma_t X_{L,t} + \bar{\ell}\sigma^2_{\ell,t} - \bar{\ell}X'_{L,t}\Sigma^{\ell}_t\right).$$

Σ_t is the conditional variance-covariance matrix for the payments on the two risky claims at time $t+1$: $\Sigma_t = VarCov(D_{t+1})$. $\sigma^2_{\ell,t}$ is the conditional variance of the payments of the debt of levered intermediaries: $\sigma_{\ell,t} = Var_t(d^{\ell}_{t+1})$. $\Sigma^{\ell}_t = (\sigma_{IR,\ell,t}, \sigma_{CR,\ell,t})'$ is the vector of conditional covariance between the payments on the two risky claims and the payments of the debt of levered intermediaries: $\sigma_{IR,\ell,t} = Cov_t(d^{IR}_{t+1}, d^{\ell}_{t+1})$ and $\sigma_{CR,\ell,t} = Cov_t(d^{CR}_{t+1}, d^{\ell}_{t+1})$.

The optimality conditions for the levered intermediary is:

$$P_t = E\left[M^a_{t+1}\left(P_{t+1} + D_{t+1}\right)\right] - \underbrace{\psi\Sigma_t X_{L,t}}_{\substack{\text{Regulatory}\\ \text{Cost}}} + \underbrace{\psi\bar{\ell}\Sigma^{\ell}_t}_{\substack{\text{Hedging}\\ \text{Benefit}}} + \underbrace{\mu_t\Omega P_t}_{\substack{\text{Collateral}\\ \text{Benefit}}} \tag{22}$$

The equation shows that the levered intermediary trade-off the marginal increase in regulatory cost by increasing the holdings of risky assets with the hedging and collateral benefits. The optimality condition of the asset managers are instead:

$$P_t = E\left[M^a_{t+1}\left(P_{t+1} + D_{t+1}\right)\right]. \tag{23}$$

The asset managers does not have any regulatory concern and therefore only invest in the assets because of their future payoff. Using Equation 22 and 23, we find the optimal allocation of the levered intermediary:

$$X_{L,t+1} = \underbrace{\bar{\ell}\Sigma^{-1}\Sigma^{\ell}}_{\substack{\text{Hedging}\\ \text{Term}}} + \underbrace{\frac{\mu^B}{\psi}\Sigma^{-1}\Omega P}_{\substack{\text{Collateral}\\ \text{Term}}}. \tag{24}$$

Allocation to IR Using the orthogonality of the two factors, we could write the allocations to interest rate risk:

$$X^{IR}_{I,t+1} = \underbrace{\bar{\ell}\frac{\sigma_{IR,\ell,t}}{\sigma^2_{IR,t}}}_{\substack{\text{Hedging}\\ \text{Term}}} + \underbrace{\frac{\mu^B}{\psi}\frac{\omega^{IR}}{\sigma^2_{IR,t}}P}_{\substack{\text{Collateral}\\ \text{Term}}}$$

The first term, on the right hand side, is the hedging term. It states that the intermediaries tilts their portfolio to assets with higher covariance with their liabilities, per unit of squared risk. The first term is particularly relevant for insurance companies and pension funds. These intermediaries have long-term liability, which are marked-to-market using the risk-free swap curve. That negatively expose their balance sheet to interest rate risk. The hedging motive of insurance companies and pension funds explains the allocation to safe long-term bonds.

The second term, is the collateral term. Levered intermediaries are able to take leverage using assets as collateral. However, it is more costly for them to hold risk (due to the regulatory cost).

They then allocate more of their portfolio to assets which provide better collateral per unit of squared risk. The higher the ω, the higher the allocation to the risk factors.

Allocation to CR The allocation to credit risk is instead defined by:

$$X_{I,t+1}^{CR} = \underbrace{\frac{\mu^B}{\psi} \frac{\omega^{CR}}{\sigma_{CR}^2} P}_{\substack{\text{Collateral} \\ \text{Term}}}.$$

Levered intermediaries allocate their portfolio to credit risk insofar as it provides collateral value. The credit risk, instead does not provide any hedging value.

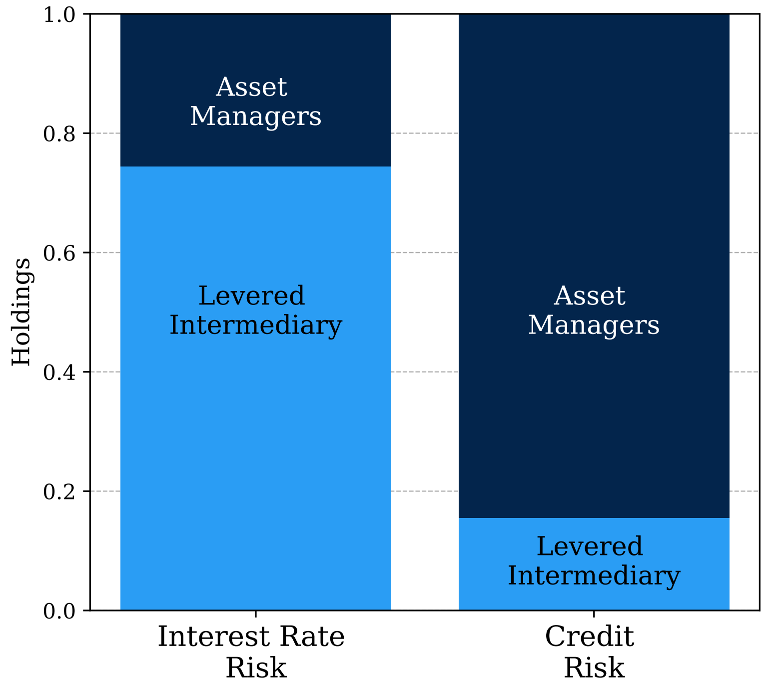
Figure 10 plots the allocation across the two types of risks of asset managers and levered intermediaries.[15] The figures shows that levered intermediary holds a larger share of interest rate risk while mutual funds hold larger share of credit risk.

These results would suggest that—because of the different structure of their liabilities—asset managers and levered intermediaries choose to be exposed to different risk. Levered intermediaries, such as ICPFs, select into assets with a high interest-rate risk exposure to match their long-duration liabilities. For asset managers, this liability-matching motive is absent, and they instead select into securities carrying credit risk as they do not face any regulatory cost in doing so. The wealth allocation decision of the household investing through the different intermediaries is motivated by the trade-off between the ability to take leverage and the cost of regulation. They, therefore, allocate part of their wealth to levered intermediaries because of their ability to issue debt and the remainder to mutual funds because of their relatively lighter regulation on risk-taking.

A key measure for our allocation is the hedging term: $\frac{\sigma_{IR,\ell,t}}{\sigma_{IR,t}^2}$. In our model, the IR claim and the CR claim are exposed to only the IR risk factor and CR risk factor, respectively. However, this measure can be empirically estimated for all bonds. In Appendix E.5, we discuss how to empirically estimate this measure and show how bonds with higher credit risk provide inferior hedging for the liability of levered intermediaries.

[15] The figure shows the allocations $(\tilde{X}_t^L, \tilde{X}_t^M)$, for an economy where $\{X_{CB,t}, b_t^{CB}\}_{t=0}^{\infty} = 0$ and for the value of shocks equal to 0: $f_t^{IR} = f_t^{CR} = 0$

Figure 10: Allocation Across Risky Claims



Note: The figure shows the allocation across risky claims of the two type of intermediary. The left bar plots the shares of the IR claim while the right bar plots the shares of the CR claim. The figure is based on the parametrization describe in Section 5.1.9.

5.2.2 Asset Pricing

We now discuss the asset pricing implications of the model for the risk premia on the two claims. We define the risk premia as:

$$E_t\left[R^i_{t+1} - R^f_t\right],$$

for $i = IR, CR$, where

$$R^i_{t+1} = \frac{P^i_{t+1} + d^i_{t+1}}{P^i_t},$$

and

$$R^f_t = E_t\left[M^e_{t+1}\right].$$

In the model, as both intermediaries are held by the active investors and use their SDF to price the assets, the risk premium is determined by the covariance between C^a_t and V^a_{t+1} with the returns on the two risky claims. Furthermore, combining the balance sheets of the entrepreneur with the balance sheets of intermediaries, we have:

$$
\begin{aligned}
C_t^a &= \pi_t^M + \pi_t^I + T_t^a + \frac{\psi}{2} Var(\tilde{\pi}_{t+1}^L) \\
&= \underbrace{\theta^{CR} d_t^{CR}}_{\substack{\text{CR} \\ \text{Risk}}} + \underbrace{\theta^{IR} d_t^{IR} - \ell_t d_t^{\ell}}_{\substack{\text{IR} \\ \text{Risk}}}.
\end{aligned}
$$

The consumption path of the entrepreneur depends on the total supply of credit risk and the *net* supply of interest rate risk. The larger the β^ℓ of the debt of the levered intermediaries, the smaller the risk-premium on interest rate risk. The model highlights the relevance of the liability of the intermediary for the differential pricing of interest rate risk vis-a-vis credit risk. A large levered intermediary sector (i.e., a large insurance corporations and pension fund sector) reduces the exposure of the intermediary shareholders to interest rate risk and lower risk premium. While the intermediary sector (and hence the intermediary shareholders) has to absorb the supply of interest rate risk, is able to offload some of the risk to the passive households. This result also explains the findings of Greenwood and Vissing-Jorgensen (2018), which documents the effect of pension and insurance company assets on the long end of the yield curve.

5.2.3 Transmission of Monetary Policy Through Different Balance Sheets

The central bank portfolio $X_{CB,t}, b_t^{CB}$ alters the equilibrium allocation and asset prices. The model predicts that—as heterogeneous intermediaries have different allocations—the monetary policy transmission depends on the policy package.

The total net-supply of assets available to intermediaries is now:

$$
X_{L,t} + X_{M,t} = \Theta - X_{CB,t}.
$$

The sorting into different markets will heterogeneously expose intermediaries to different policy packages. If the Central bank mainly absorbs interest rate risk, this will i) imply a reduction of interest rate risk exposure of levered intermediaries. If the Central bank absorbs credit risk, this mainly affects the balance sheets of mutual funds.

To provide further insight into the mechanism of the model, we study the equilibrium allocation and asset pricing in an economy with a time-invariant central bank allocation $\bar{X}_{CB}, \bar{b}^{CB}$ and an invariant price for $q^{CB} = \beta^a$. Given the benchmark economy price: $\tilde{P}$, we define central banks policy such that:

$$
\tilde{P}' \bar{X}_{CB} = \bar{q}^{CB} \bar{b}^{CB}.
$$

One we consolidate balance sheets, the consumption path of the active households is:

$$C_t^a = \underbrace{\left(\theta^{CR} - \varphi \bar{x}_{CR}^{CB}\right) d_t^{CR}}_{\substack{\text{CR} \\ \text{Risk}}} + \underbrace{\left(\theta^{IR} - \varphi \bar{x}_{CR}^{CB}\right) d_t^{IR} - \bar{\ell} d_t^{\ell}}_{\substack{\text{IR} \\ \text{Risk}}} + \underbrace{\varphi \bar{b}^G (1 - \bar{q}^{CB})}_{\text{Risk-free}}.$$

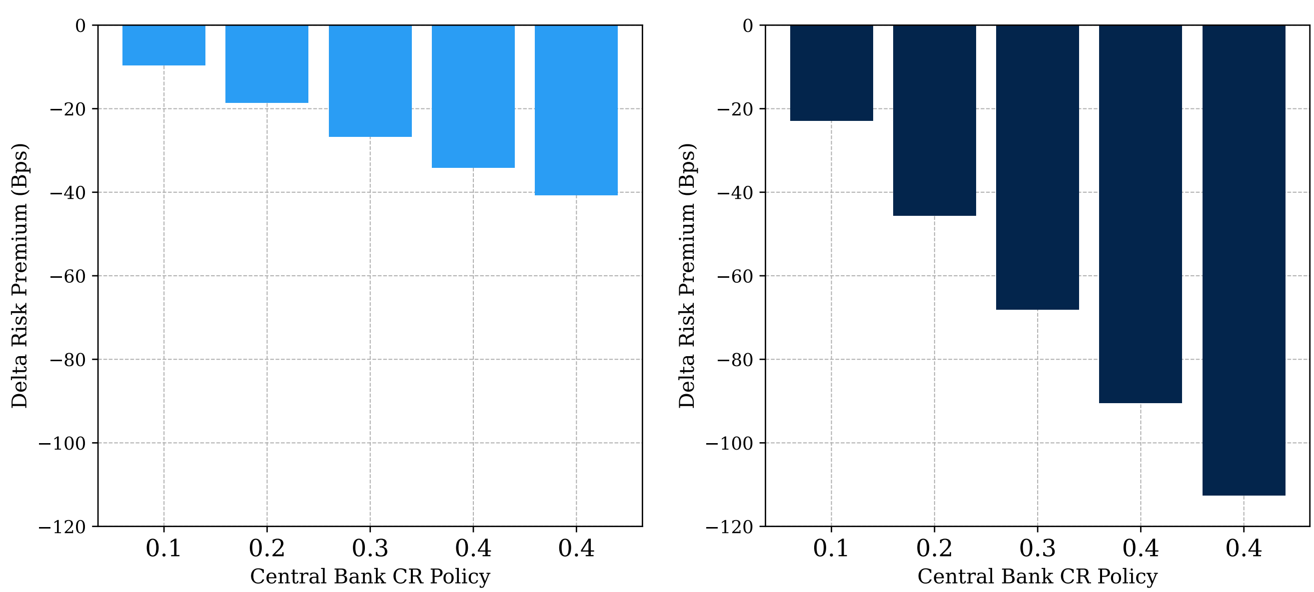
Central bank policy affects the exposure to the risk of the active households by affecting the riskiness of intermediaries' balance sheets. If the central bank buys credit risk, it reduces the net credit risk exposure and, in turn, the risk-premium commanded on credit risk. By contrast, if the central bank buys interest rate risk, it reduces the net interest rate risk exposure, and in turn, the risk-premium commanded on interest rate risk.

The different effects of different policies are a crucial element in our model. Depending on their balance sheet policy, the central bank can heterogeneously affect different risk premia. We let intermediaries endogenously sort into different risks in the model without any exogenous segmentation.

Figure 11 shows the effects for different central bank CR holdings. The effects on the credit risk premium (Figure 11a) is stronger than the effects on interest rate risk premium (Figure 11b).

Figure 11: Holding shares and Bond Sensitivity to TS Shocks

(a) Effects on IR risk premium (b) Effects on CR risk premium



Note: The figure plots the effects on risk premia due to different central bank policies. We estimate the counterfactual difference in risk premia for different amount of CR claim absorbed by the central bank: 0.1, 0.2, 0.3, 0.4. Figure 11a plots the change in IR risk premium while Figure 11b plots the change in the CR risk premium. The figure is based on the parametrization describe in Section 5.1.9.

To sum up, the model shows that levered intermediaries choose to be exposed to interest rate risk. Central bank policies that absorb interest rate risk, such as (safe) government bond purchases, mainly affect the market price of interest rate risk and, therefore, the balance sheet of levered intermediaries. On the other hand, asset managers choose to be exposed to credit risk; a central bank policy that absorbs credit risk, such as corporate bond purchases, mainly affects the balance sheet of asset managers.

5.2.4 Redistributive Implications

The model also shows that central banks' policies have implications for passive households, who do not actively invest in risky claims. The consumption of the passive household is:

$$\begin{aligned} C_t^p &= y^p + \bar{\ell} d_t^\ell + \underbrace{T_t^p}_{\substack{\text{Taxes/}\\ \text{Rebate}}} \\ &= y^p + \underbrace{\varphi \bar{X}_{CR,t}^G d_t^{CR}}_{\substack{\text{CR}\\ \text{Risk}}} + \underbrace{\varphi \bar{X}_{IR}^G + \bar{\ell} d_t^\ell}_{\substack{\text{IR}\\ \text{Risk}}} - \underbrace{(1-\varphi)\bar{b}^G(1-\bar{b}^G)}_{\text{Risk-free}}. \end{aligned}$$

Central bank policies alter the consumption path of households by exposing them to credit risk and additional interest rate risk. The balance sheet of the central bank is risky, and the risk has to be borne by the household sector ultimately.

6. Risk Allocation and the Cross-Sectional effects of Monetary Policy Shocks

The fixed-income model, described in Section 5, explain why (i) different intermediaries choose different risk exposure and (ii) why different central bank policies (i.e., different risk absorption) have heterogeneous effects on risk premia. In the model, we determine the price of the two assets, which are exposed to the interest-rate risk factor and the credit risk factor. We can then think of the cross-section of bonds in the economy as a linear combination of the prices of the two assets. In a standard factor model (e.g., Fama and French 1993), individual bond returns are based on equation:

$$R_{i,t+1} - R_t^f = \alpha_i + \beta_i^{IR}(R_{t+1}^{IR} - R_t^f) + \beta_i^{CR}(R_{t+1}^{CR} - R_t^f) + \varepsilon_{i,t+1}, \tag{25}$$

where R_{t+1}^{IR} are the returns on the interest rate portfolio and R_{t+1}^{CR} are the returns the credit risk portfolio. Begenau, Piazzesi, and Schneider (2015) uses the return on a safe zero coupon bond swap with a maturity of five years as interest-rate portfolio and the return on a leveraged portfolio that combines borrowing at the 5-year swap rate with investment in higher risk BBB-rated bonds as a proxy for the credit risk portfolio. The risk premium on each individual bond is then:

$$E\left[R_{i,t} - R_t^f\right] = \alpha_i + \beta_i^{IR} \underbrace{\lambda^{IR}}_{\substack{\text{Interest-Rate} \\ \text{Risk Premium}}} + \beta_i^{CR} \underbrace{\lambda^{CR}}_{\substack{\text{Credit} \\ \text{Risk Premium}}} .$$

In this factor approach, the central bank policies affect the risk premia on the two factors, λ^{IR} and λ^{CR}. As discussed, the effects of central bank policies on risk premia are determined by the type of policy tools. The cross-sectional effects are instead pinned down by the loadings on risk factors, i.e., β_i^{IR} and β_i^{CR}.

The correlation observed between intermediary holdings and the sensitivity of bonds to the different shocks can then be explained by the following three findings: (i) different monetary policy instruments have different transmissions: a credit risk absorption (e.g., through corporate sector purchases) mainly affects credit risk premium while an interest rate risk absorption (e.g., through government sector purchases) mainly affects interest rate risk premium (ii) a selection mechanism: insurance companies and pension funds select into corporate bonds with higher loadings on interest-rate risk (i.e., high β_i^{IR}) while mutual funds select into corporate bonds with high credit risk exposure (i.e., high β_i^{CR}) and, (iii) bonds with higher β_i^{CR} are more responsive to credit risk shocks while bonds with higher β_i^{IR} are more responsive to interest rate risk shocks.

The model explains why intermediaries choose to be exposed to different risk factors. We now provide empirical evidence to document the sorting in the corporate bond market.

6.1 Risk Allocation

We rank bonds according to maturity and credit risk to provide empirical evidence on the sorting in the corporate bond market. We sample bonds into ten maturity deciles, where the 1st decile includes the shortest maturity bonds, and the 10th decile includes the longest maturity bonds.[16] To measure credit risk, we use the credit-spread decile of the bond.

For each group of bonds, we calculate the average share held by the different intermediary types by pooling data across the whole sample.[17]

Figure 12a reports the holding share in each risk-decile. The Figure clearly shows that mutual funds select into credit-riskier bonds. While mutual funds hold only 20% of the safest bonds, they hold almost 50% of the riskiest group. Insurance companies hold instead higher shares (around 35%) of the safest bonds, while their shares drop dramatically for the riskier deciles (they hold only 10% of the 10th risk decile).

Figure 19a in Appendix A also includes holdings by banks. Banks holds safe short-term

[16] The average maturity for each decile is: 1.5, 2.3, 3.0, 3.8, 4.5, 5.2, 6.1, 7.1, 8.6, 12.5. This exercise only considers bonds with a maturity greater than one year.

[17] We only include the sample of bonds available in iBoxx. The sample is, therefore the same used in our estimates in Section 4.

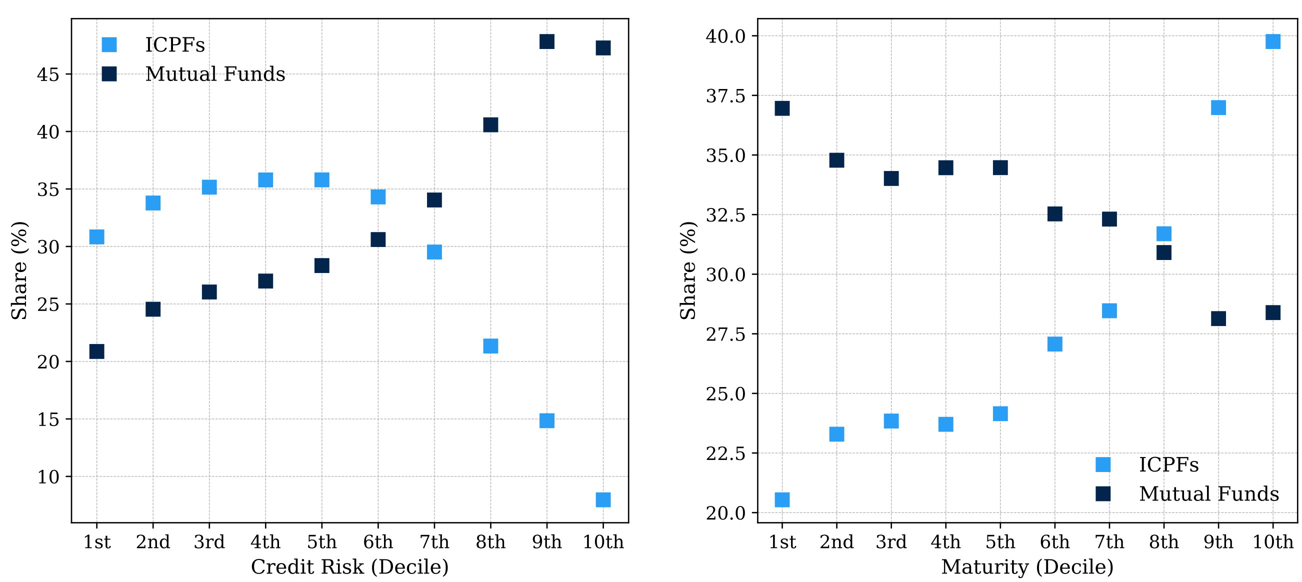
maturity bonds. This explains the non-monotonic decrease in shares by insurance companies and pension funds in Figure 12a. In Appendix A, Figure 17 shows the sorting by different credit ratings.

By contrast, insurance companies and pension funds (ICPF) have larger share of long maturity bonds, as displayed in Figure 12b. They hold roughly 20% of the shorter maturity bonds and 40% of the longer maturity bonds.

Figure 12: Allocation by Risk and Maturity

(a) Allocation by Risk Decile

(b) Allocation by Maturity Decile



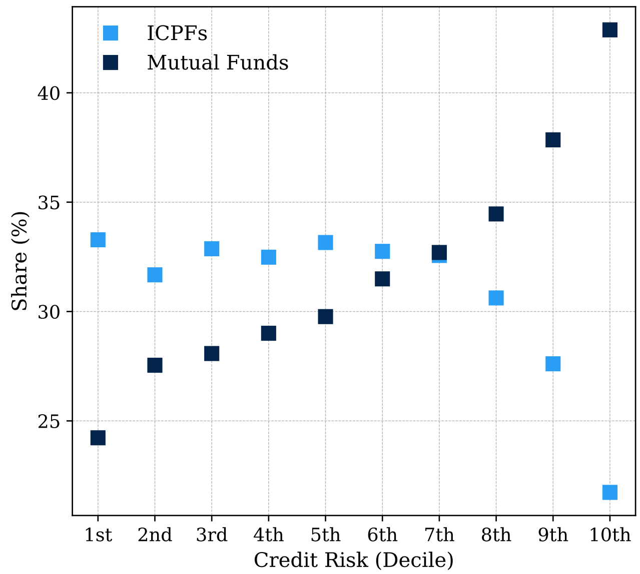
Note: The figure plots the average shares of insurance corporation and pension funds (ICPF) and mutual funds (MF) for different bond group. We divided bond based on their credit risk (Figure 12a and maturity (Figure 12b. We only include bonds available both on iBoxx and on SHS and we estimate shares by pooling data across the full sample. The sample runs from 2014 to 2021. Source: Markit iBoxx and SHS. Source: Markit iBoxx and ECB SHSS.

To further convey the importance of using the yield spread (and not only ratings, in Figure 13, we restrict our sample to corporate bonds with BBB ratings. We then rank to bonds according to credit risk decile (within the BBB rating sample), and compute the shares held by ICPFs and mutual funds. We find a striking sorting within the BBB-rated bonds. Mutual funds hold more of the riskier corporate bonds while insurance companiens and pension funds hold more of the safer bonds.

6.1.1 Factor Allocation

To further illustrate the selection mechanism, in this section, we summarize the risk-exposure using two key risk factors of the corporate bond market: interest rate risk and credit risk. We

Figure 13: BBB Corporate Bonds: Allocation by Risk Decile



Note: In this figure, we restrict our sample to corporate bonds with BBB ratings. We then rank to bonds according to credit risk decile (within the BBB rating sample), where the 1st decile are credit-safest bonds while the 10th are the credit-riskiest bonds. Finally, we compute the shares held by ICPFs and mutual funds. We only include bonds available both on iBoxx and on SHS and we estimate shares by pooling data across the full sample. The sample runs from 2014 to 2021. Source: Markit iBoxx and SHS.

use an empirical factor model to capture the risk exposure of each corporate bonds and, using the data on asset holdings, we match each corporate bond position to its risk exposure.

Risk Factors We measure two risk-factors for the corporate bond market. One risk-factor that measure interest rate risk (IR) and one risk-factor that measure credit risk (CR). We construct two market portfolios to replicate the returns of the two factors. The first portfolio is constructed as the value-weighted return on the credit-risk-free component of our corporate bond index: the interest rate risk factor (R^{IR}). The second risk-factor is constructed using the value-weighted excess return (vis-a-vis a credit-risk-free bonds with equal maturity) on all BBB corporate bonds: the credit risk factor (R^{CR}). The return of any corporate bond can then be defined as in Equation 25.

Risk Exposure We use corporate bond characteristics (rating and maturity), to estimate the risk-exposure of a single corporate bonds. We run the following panel regression:

$$\begin{aligned} R_{i,t+1} = {} & \beta^{IR}_{Rat,j} R^{IR}_{t+1} \times \mathbb{1}^{Rat}_j + \beta^{IR}_{Mat,j} R^{IR}_{t+1} \times \mathbb{1}^{Mat}_j \\ & + \beta^{CR}_{Rat,j} R^{CR}_{t+1} \times \mathbb{1}^{Rat}_j + \beta^{CR}_{Mat,j} R^{CR}_{t+1} \times \mathbb{1}^{Mat}_j \qquad (26) \\ & + \text{Level Dummies} + \varepsilon_{i,t}, \qquad (27) \end{aligned}$$

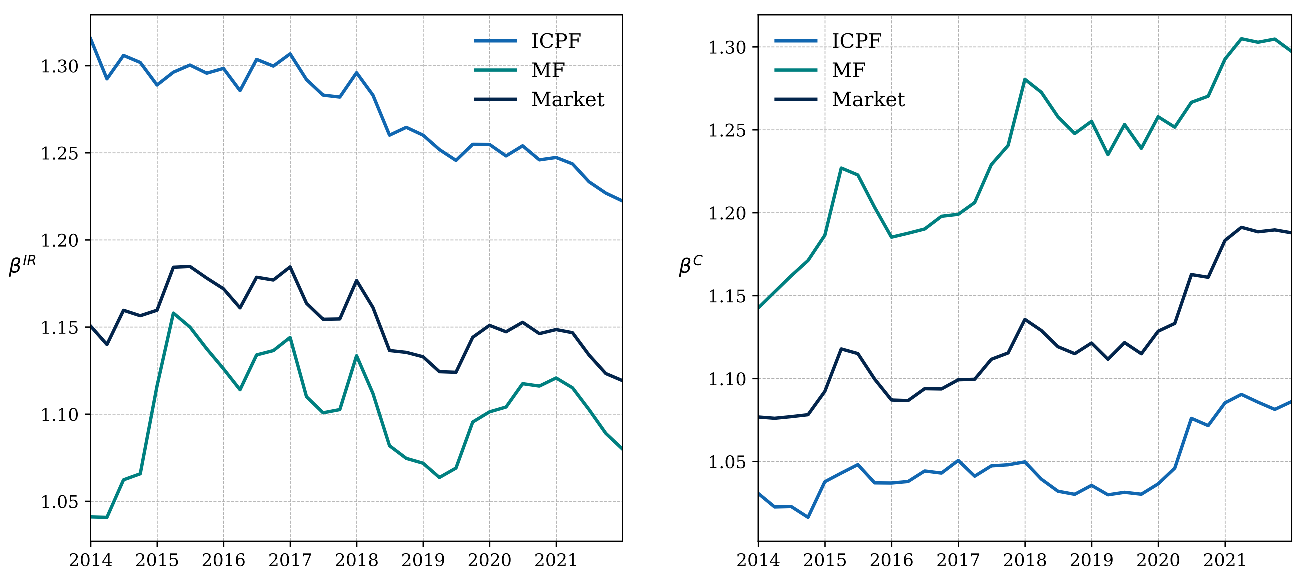
where $\mathbb{1}^{Rat}_j$ is a dummy equal to 1 if the bond belongs to the j^{th} rating group and $\mathbb{1}^{Mat}_j$ is a dummy equal to 1 if the bond belongs to the j^{th} maturity group. Level Dummies is the set of non-interacted dummies. The exposure to interest rate risk of a bond with rating of j and maturity j is given by the two estimated $\beta^{IR}_{Rat,j}$ and $\beta^{IR}_{Mat,j}$. The exposure of the bond to credit risk is measured through the estimated $\beta^{CR}_{Rat,j}$ and $\beta^{CR}_{Mat,j}$.

With our estimated β exposure for each corporate bond, we calculate the overall exposure of the corporate bond portfolio of ICPF and mutual funds, as well the overall exposure of all private investors in the Euro area (the Market exposure). We compute the overall exposure for each quarter from 2013Q4 to 2021Q4.[18] We compute the risk exposure for the *market*, which consists of the whole Euro area (combining all sectors). We then also compute the exposure for the insurance corporation and pension fund sector (ICPFs) and the mutual fund sector (MF).

Figure 14 collect our results. The figure clearly shows that ICPF have high interest rate risk (IR) exposure and low credit risk (CR) exposure, compared to the market. By contrast mutual funds exhibit high exposure to credit risk and lower exposure to IR risk than the market.

Figure 14: Risk Exposure

(a) IR Beta of Portfolio (b) Credit Beta of Portfolio



Note: The figure plots the risk exposure to interest rate risk (Figure 14a) and credit risk (Figure 14b for different sectors: the mutual fund sector (MF), the insurance corporations and pension funds sector (ICPFs) and the combined Euro area sectors (the market). We estimate the risk exposure for every single security by way of Equation 27 and use holdings data from SHS to aggregate exposures to the sector level. Sample: 2013-Q4 to 2021-Q4. Source: Markit iBoxx and SHS.

[18] We use β estimated over the entire sample. The time variation is given by the change in portfolio weights over time.

6.2 Bond Response to ECB Policies

We now further discuss the main source of heterogeneity in bonds yields sensitivity to credit shocks. We sort bonds according to yield spread and maturity decile.[19] However, we also report results by using the rating as a single measure of credit risk.

We then regress:

$$\Delta ys_{i,t} = \gamma_i + \gamma_t + \beta_j^{Risk} MP_t^{CS} \times \mathbb{1}_j^{Risk} + \beta_j^{Mat} MP_t^{CS} \times \mathbb{1}_j^{Mat} + \gamma_j^{Risk} \mathbb{1}_j^{Risk} + \gamma_j^{Mat} \mathbb{1}_j^{Mat} + \varepsilon_{i,t}, \quad (28)$$

where $\mathbb{1}_j^{Risk}$ is the dummy that indicates whether the bonds belong to the j^{th} risk bucket and $\mathbb{1}_j^{Mat}$ is the dummy that indicates whether the bonds belong to the j^{th} maturity bucket. γ_i and γ_t are bond and time fixed-effects.

The coefficients of interests are: β_j^{Risk} and β_j^{Mat}, which measure how the sensitivity of corporate bonds vary with credit-risk and maturity, respectively.

Figure 15 plots the estimated coefficients from Equation 28 together with the confidence bands.[20] The coefficients are estimated relative to the first riskiness and maturity group. Figure 15a displayed the estimated β_j^{Risk}. The figure clearly shows that the sensitivity to credit spread shocks increase with risk. Figure 15b display the estimated β_j^{Mat} together with their confidence bands. The figure shows that for short to medium maturity the response of bonds is increasing. However, for longer-maturity bonds (with maturity above 4.5) it seems the sensitivity is lower.

Figure 23 shows the results for Equation 28 where we used ratings instead of credit-risk deciles. The results in Figure 23a are broadly in line with our previous results.

The combination of the results in Figure 15a and Figure 23b suggest that the sensitivity of corporate bonds to credit spread shocks is increasing with the risk of the bonds. Within a credit rating, it seems that the term-structure of credit risk is increasing: longer-maturity bonds have higher credit spread than shorter maturity bonds. Therefore, if we capture credit risk through the priced yield-spread—which should take into account all characteristics contributing to credit risk—the results suggest the maturity of the bonds is less important in determining the sensitivity of bonds to ECB credit spread shocks.

6.2.1 The Effects on Non-Investment Grade Bonds

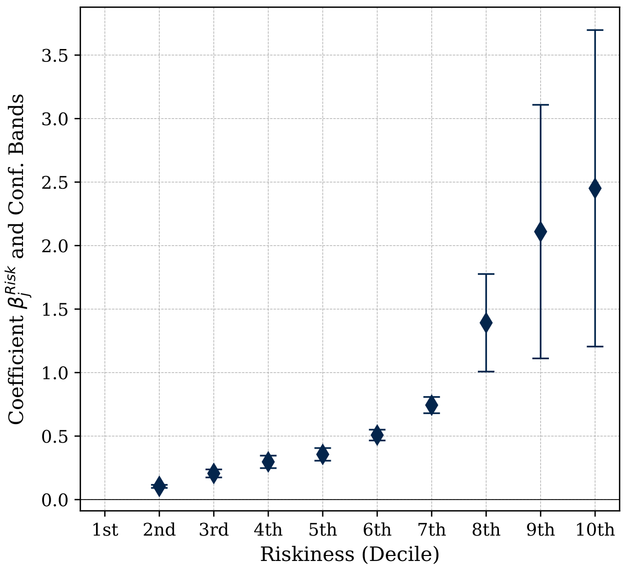
Figure 4 clearly shows that credit spreads have been reduced by the action of the central bank. However, as discussed, the ECB only purchased investment-grade corporate bonds. Their purchases have not been extended to sub-investment grade bonds. Haddad et al. (2021) showed that in the US, they did not observe any effects on sub-investment grade bonds, consistently with the

[19]The category are the same as discussed in Section 6.1

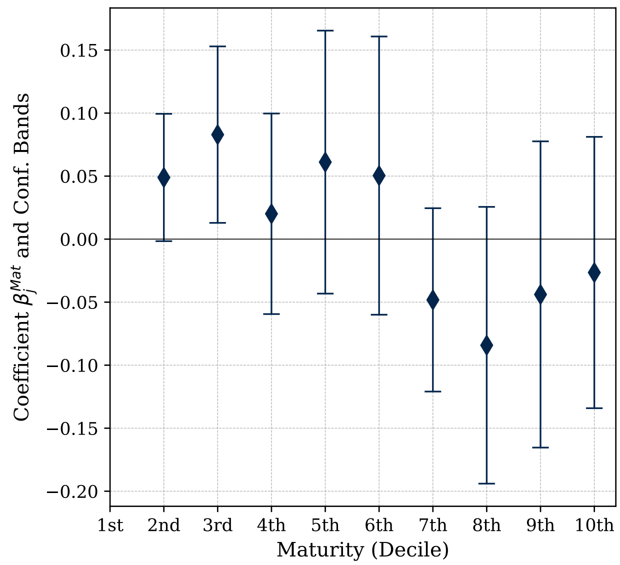
[20]Confidence bands are based on standard errors clustered at the ISIN-Time level.

Figure 15: Sensitivity to MP^{CS} by Credit Risk and Maturity

(a) Sensitivity to MP^{CS} by Credit Risk Decile



(b) Sensitivity to MP^{CS} Shocks by Maturity Decile



Note: The figure shows the estimated coefficient from Equation 28. Figure 15a displayed the estimated β_j^{Risk} together with their confidence bands. Figure 15b display the estimated β_j^{Mat} together with their confidence bands. The sample runs from 2014 through 2021. The coefficients are estimated relative to the first riskiness and maturity group (for this reason, the coefficient for the first group are missing). Source: Markit iBoxx.

narrow channel of QE.

The ECB only bought corporate bonds whose best rating (S&P, Fitch, Moody's, and DBRS) is at least BBB-. Using our micro data, we compute the change in yields on the week of the CSPP announcement[21] and estimate the average change by rating group. We also further split the sample in short maturity bonds (maturity less or equal to four years) and long-maturity bonds. The results are displayed in Figure 16a: every point in the figure is the estimated change in yield for the corresponding rating-maturity group. Figure 16a suggests that bonds beyond the ECB cutoff (BB+ or worse) were notably affected by the ECB policy. We also note that, among the investment grade bonds, long-maturity bonds saw a larger compression in yields than short-maturity (as also discussed by Todorov (2020)). However, according to Figure 16a seems that the riskiness of the bonds explains most of the cross-section variation. In fact, in contrast to the US experience, our results suggest that high-yields bonds, seemed to be those that benefited the most by the ECB credit policy.

The bond yields behavior around the PEPP announcement also corroborates this conclusion. In Figure 16b we plot the evolution of bond yields in the first semester of 2020. The high-yields

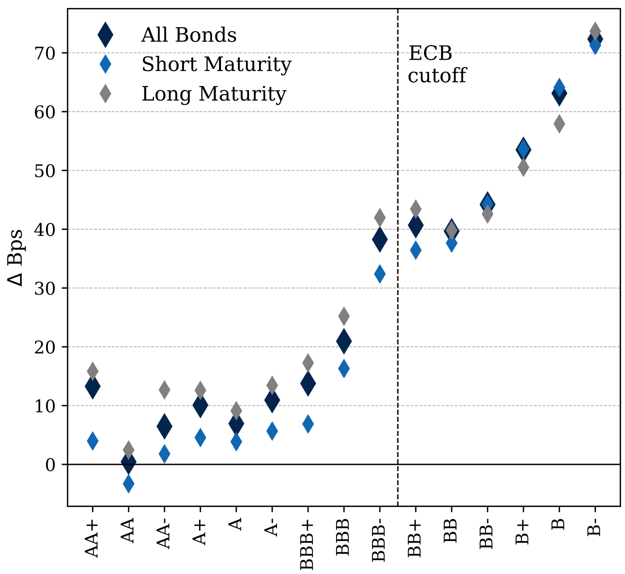
[21] To make sure our results are not driven by noise, we take a number of step. We compute the average yield for each bond one week after the announcement of CSPP and measure the difference with respect two days before the announcement. We drop outliers and compute the average change for each rating bucket.

bonds, in orange colors, spiked in March 2020 to then retract after the announcement of the massive bond intervention of the ECB. The size and speed of the fall in bond yields by high-yield bonds is unprecedented. Although the effects on investment-grade bonds is also notable—as the PEPP managed to stop the rising cost of bond funding all across the board—the pandemic experience also confirmed the potent effects of ECB actions on high-yields bonds.

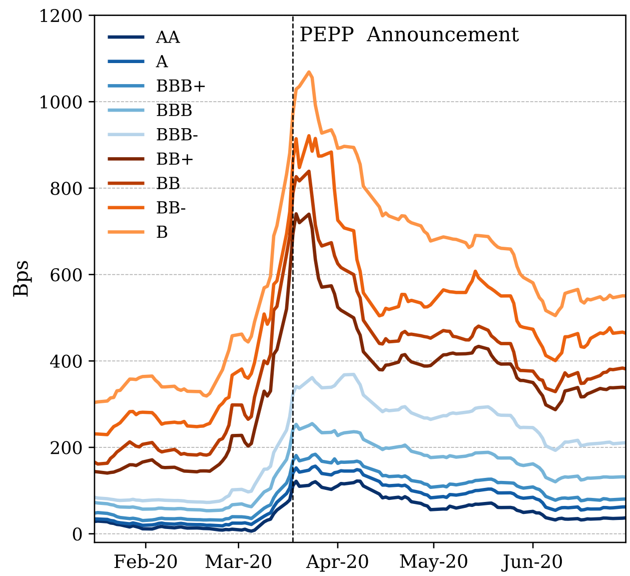
Figure 16 is based on micro-data on bond prices from Markit-iBoxx. We also replicate the results using a different datasource: aggregate option-adjusted-yield spread from the Bloomberg-Barclays index. The results, reported in Figure 21 in Appendix B, are virtually identical, both for the CSPP as well as the PEPP announcements.

Figure 16: CSPP and PEPP announcement - by Rating

(a) Response to CSPP Announcement - by Rating



(b) PEPP Announcement - by Ratings



Note: The figure shows the change in bond yields around ECB CSPP and PEPP announcement. We compute the average yield for each rating group (and maturity group). Figure 16a shows the change in yields in the week of the CSPP announcement. Figure 16b shows the evolution of bond yields around the PEPP announcement.Source: Markit iBoxx.

7. Conclusion

This paper studies the transmission of ECB monetary policy to the Euro area corporate bond market. We construct two monetary policy shock series and show that their transmission depends on the type of policy instrument used by the central bank. The first shock, the credit spread monetary policy shock is measured using the change in corporate bond yield spread around ECB announcement. The second shock, the term spread monetary policy shock, is measured as the change in term spread (10 year OIS minus 2 year OIS) around ECB announcements.

We show that different policy instrument transmit through different shocks. A corporate bond purchases mainly affect the credit spread shock. A (safe) government bond purchases mainly affect the term spread shock. With the two shocks at hand, we measure the cross-sectional effects of monetary policy on the corporate bond market. Based on granular information from the ECB Security Holdings Statistics, we document that the yield on bonds held by different intermediaries respond heterogeneously to the two shocks: bonds held by mutual funds exhibit a higher sensitivity to the credit spread shocks, while bonds held by insurance companies and pension funds (ICPFs) are more sensitive to the term spread shocks.

We also show that these correlation mainly arise because of different intermediaries choose to be exposed to different risks: ICPFs select into assets with a high interest rate risk exposure (credit safe, long maturity bonds) while mutual funds select instead into securities carrying credit risk (credit risky bonds).

We explain these findings through the lens of a model of the fixed income market with multiple risk factors and heterogeneous intermediaries. Levered intermediaries, such as ICPFs, select into assets with a high interest rate risk exposure to match their long-duration liabilities. For mutual funds, this liability-matching motive is absent, and they instead select into securities carrying credit risk.

Different policy tools heterogeneously affect the market prices of those factors. In our model, the transmission channel of central bank purchases is through risk-shifting: the central bank, by purchasing financial assets, extracts risks from the market, previously held by private intermediaries. In turn, this affects the risk exposure of intermediaries shareholders—a subset of the household sector—and hence alter the market price of risk. Different monetary policy instruments absorb different types of risks and therefore have different effects on risk premia. Our results have important implications for the transmission of monetary policy, financial stability and redistribution.

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A. The Euro Area Corporate Bond Market

We analyze the Euro area corporate bond market using the total amount of holdings by private investors in the Euro area. These data are based on information from the SHS database.

Issuer Sector Table V reports data for the Euro area corporate bond market by issuer sector. The first column reports the total amount in Eur bilions of holdings by Euro area private sector investors. The second to fifth columns reports the holding shares by different types of investors. The same columns are also reported for 2013. Note that the NFC total amount does not include holdings by the central bank, which are large—as Figure 1b has shown. The MFI sector is still the largest issuer of corporate bonds but the total amount has been roughly stable since 2013. This contrasts with the notable increase in NFC corporate bonds which almost doubled in the past decade from Eur 559bns to Eur 941bns. We also observe a notable increase in bonds issued by captive institutions: it is often the case that captive institutions issue bonds to NFC, showing the increase relevance of corporate bonds for NFC.

Table V: Euro Area Corporate Bond Market - Issuer

	2021					2013				
	Tot (bn)	ICPF	MF	MFI	Others	Tot (bn)	ICPF	MF	MFI	Others
MFI	1896	21.4	20.6	51.9	6.2	1903	25.1	17.0	46.6	11.4
NFC	941	42.0	43.4	8.2	6.3	559	46.5	32.9	10.1	10.6
Captive	407	33.4	48.0	9.4	9.3	4	46.0	44.5	6.9	2.6
OFI	575	25.2	28.8	40.8	5.3	939	26.3	24.2	39.1	10.4
ICPF	31	47.8	39.9	3.7	8.6	10	58.0	19.0	12.7	10.4
F. Auxiliaries	116	39.8	45.2	7.2	7.8	6	29.3	41.8	18.3	10.6

Note: Table V reports data for the Euro area corporate bond market by issuer sector. The first column reports the total amount in Eur bilions of holdings by Euro area private sector investors. The second to fifth columns reports the holding shares by different types of investors. The same columns are also reported for 2013. Source: ECB SHSSs.

Ratings We show the allocation for bonds issued by NFC according to the ratings. We show data for NFC and for all issuer sector. The first column reports the shares for each rating within the aggregate Euro area portfolio. The second to fifth columns exhibit the shares held by the different rating agencies.

Table VI: Euro Area Corporate Bond Market - Ratings

	NFC					All				
	Tot (Share)	ICPF	MF	MFI	Others	Tot (Share)	ICPF	MF	MFI	Others
AAA	1.1	59.2	25.2	10.5	5.0	26.1	16.8	15.2	62.1	5.9
AA+	0.5	51.1	18.7	27.9	2.3	5.0	13.1	10.8	73.2	3.0
AA	2.3	55.7	26.7	11.8	5.8	5.4	27.9	17.9	50.3	3.8
AA-	3.1	57.7	27.4	10.6	4.3	7.3	31.8	20.5	43.4	4.3
A+	5.5	54.2	34.4	6.7	4.7	8.0	40.1	32.1	21.6	6.1
A	7.3	49.9	34.2	10.2	5.8	8.2	37.8	35.3	20.0	6.9
A-	19.0	51.0	36.2	7.8	5.1	9.7	46.2	37.4	10.4	6.0
BBB+	22.4	49.5	38.4	8.1	4.0	11.2	39.6	38.6	16.2	5.5
BBB	14.6	40.2	44.8	9.7	5.3	7.8	34.8	46.2	12.2	6.9
BBB-	8.1	27.4	58.9	7.5	6.1	3.9	24.9	57.8	10.4	6.9
BB+	5.6	20.4	61.1	10.2	8.3	2.4	19.1	58.4	11.3	11.2
BB	3.7	17.4	67.9	5.1	9.6	1.3	16.2	66.0	7.9	10.0
BB-	1.7	12.3	65.4	5.8	16.5	0.8	11.0	62.8	8.9	17.3
B+	1.9	10.4	70.2	1.6	17.8	1.0	8.9	63.9	6.0	21.1
B	2.0	9.3	66.7	1.3	22.7	1.1	8.5	62.8	4.5	24.2
B-	0.7	5.9	61.8	0.9	31.5	0.4	5.5	67.6	2.0	24.9
$<$ B	0.4	5.6	76.2	1.7	16.5	0.4	6.1	70.0	4.8	19.1

Note: The table shows the allocation for bonds issued by NFC according to the ratings. We show data for NFC and for all issuer sector. The first column reports the shares for each rating within the aggregate Euro area portfolio. The second to fifth columns exhibit the shares held by the different rating agencies. Source: ECB SHSS.

Of the total amount of NFC corporate bonds held by Euro area private investors, 30% are issued by countries outside the Euro area, while 70% are issued by Euro area countries.

We then only select bonds issued by Government and NFC and show the allocation of mutual funds (MF), insurance corporations and pension funds and banks (MFI). Figure 17 plots the allocation of bonds issued by non-financial corporations. Figure 18 plots the allocation of total government and corporate bonds.

The table VII shows the share of bonds issued by Non-financial corporations by rating.

Table VII: Euro Area Corporate Bond Market - High Yield

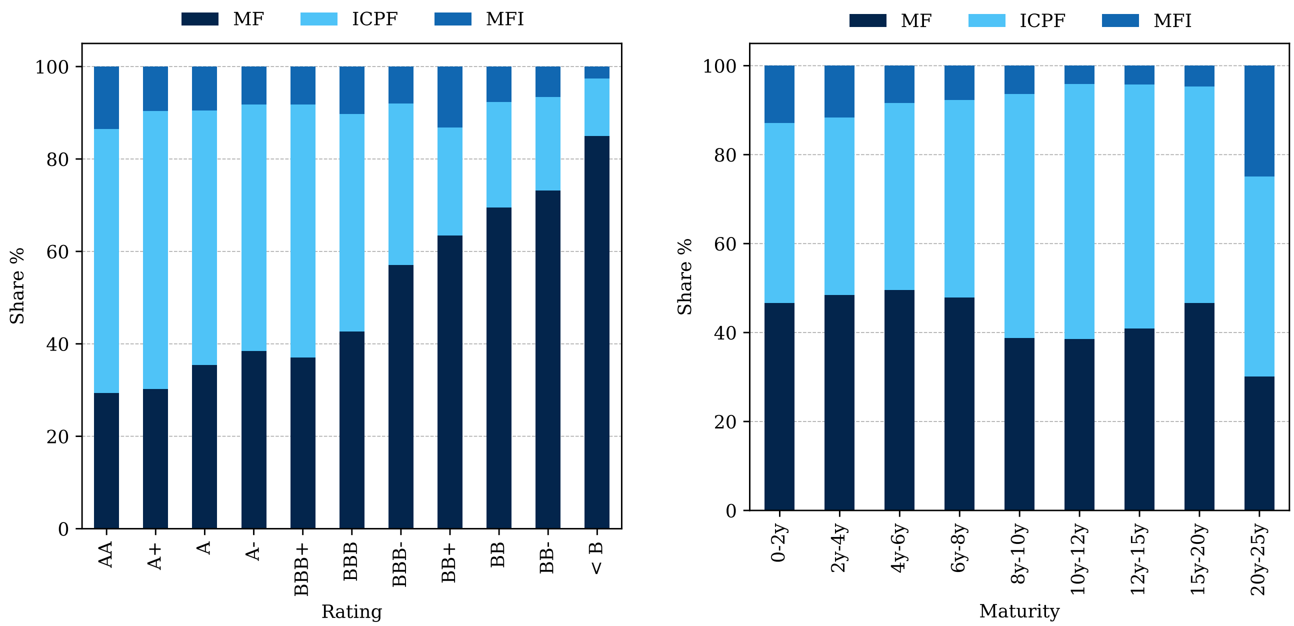
	Number of Bonds (Share)	Amount Outstanding (Share)
AAA	0.3	0.5
AA	3.7	3.1
A	20.3	22.0
BBB	48.6	50.7
HY	27.2	23.7

Note: The table shows the shares of bonds issued by Non-financial corporations by rating. Source: ECB SHS.

Figure 17: Allocation Corporate Bonds

(a) Allocation by Rating

(b) Allocation by Maturity

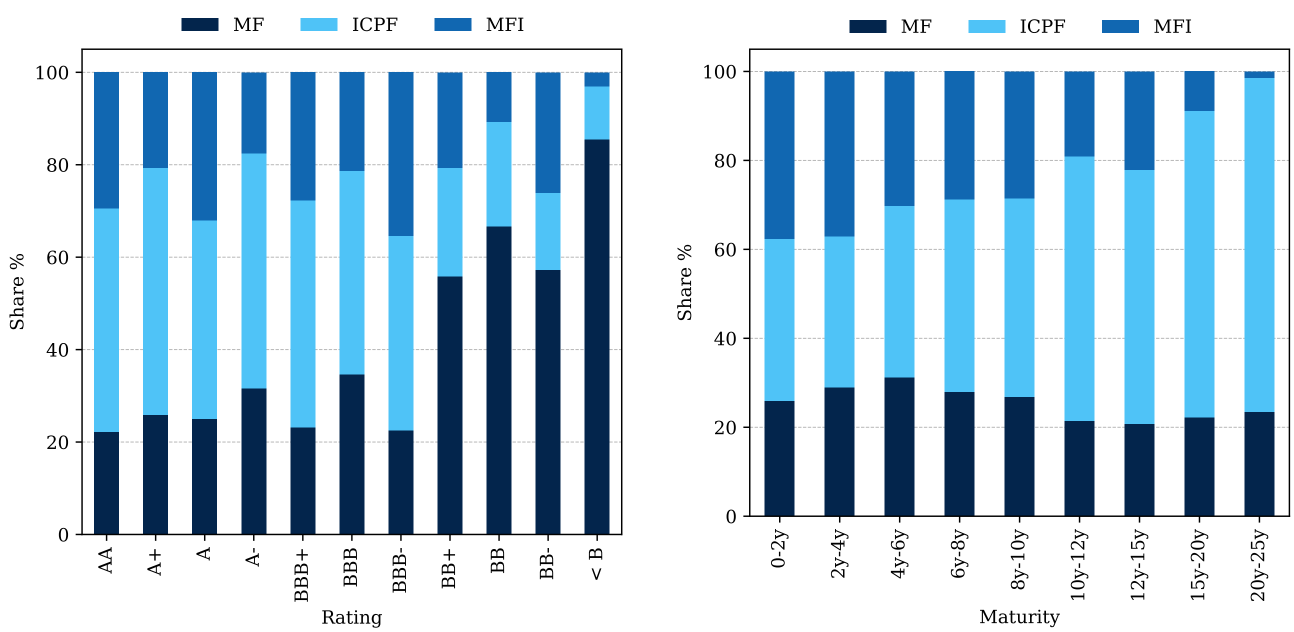


Note: Figure 17 plots the allocation of bonds issued by non-financial corporations.Source: ECB SHSSs.

Figure 18: Allocation of All Bonds (Government and Corporate Bonds)

(a) Allocation by Rating

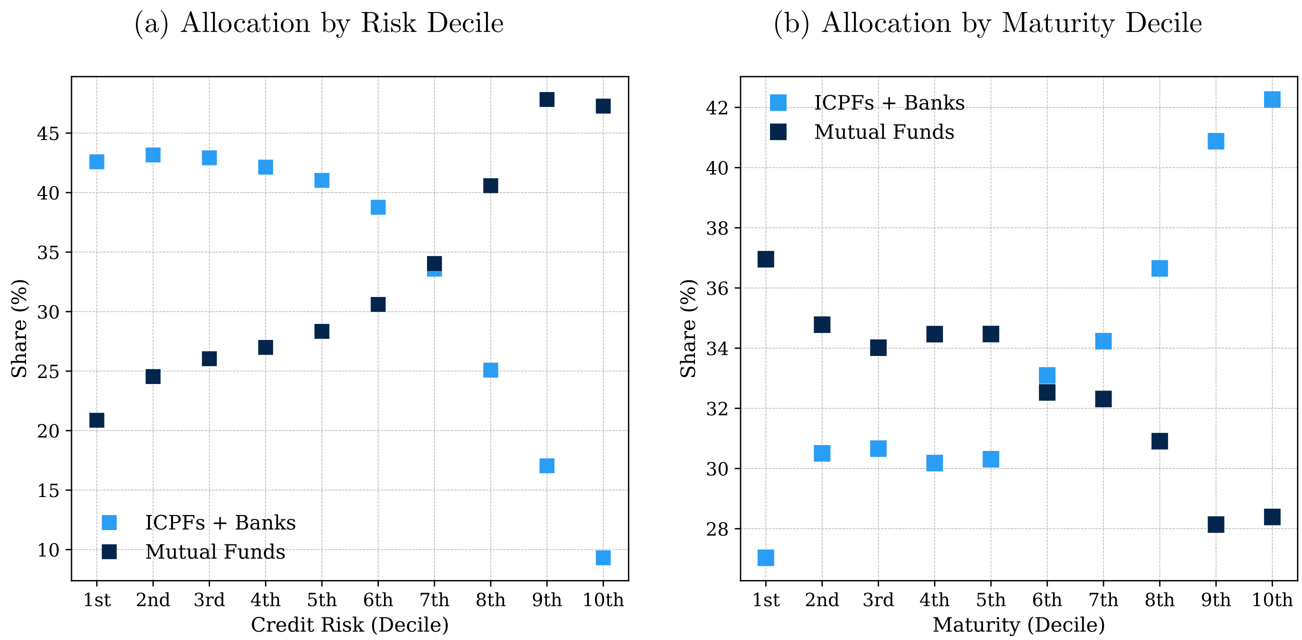
(b) Allocation by Maturity



Note: Figure 18 plots the allocation of total government and corporate bonds. Source: ECB SHSSs.

A.1 Allocation with MFI

Figure 19: Allocation by Risk and Maturity



Note: The figure plots the share held by different intermediaries. Source: Markit iBoxx, ECB SHSS.

A.2 Financial Intermediaries

A.2.1 Insurance Corporations

The total asset of insurance corporation in the Euro area accounts for 9.1tn at the end of 2021.

The insurance sector in the EU is supervised by the European Insurance and Occupational Pensions Authority (EIOPA) and is based on Solvency II, the prudential regime for insurance and reinsurance undertakings in the EU. Solvency II has a risk-based approach that enables to assess the "overall solvency" of insurance and reinsurance undertakings through quantitative and qualitative measures. The Solvency II framework set out qualitative and quantitative requirements for calculation of technical provisions and Solvency Capital Requirement (SCR).

The value of technical provision should be equal to the sum of best estimate of the liabilities and risk margin. The best estimate corresponds to the probability-weighted average of future cash-flows, discounted using the risk-free curve published by EIOPA. For Euro denominated liabilities, the risk-free curve was originally based on EONIA-OIS curve; it then transitioned to ESTR-OIS curve.[22] Technical provisions represent the current amount the (re)insurance company would have to pay for an immediate transfer of its obligations to a third party.

[22] See Appendix Data for further information on the risk-free curves.

The SCR is the capital required to ensure that the (re)insurance company will be able to meet its obligations over the next 12 months with a probability of at least 99.5%. In addition to the SCR capital a Minimum capital requirement (MCR) must be calculated which represents the threshold below which the national supervisor (regulator) would intervene. The MCR is intended to correspond to an 85% probability of adequacy over a one-year period and is bounded between 25% and 45% of the SCR.

For supervisory purposes, the SCR and MCR can be regarded as "soft" and "hard" floors respectively. That is, a regulatory ladder of intervention applies once the capital holding of the (re)insurance undertaking falls below the SCR, with the intervention becoming progressively more intense as the capital holding approaches the MCR.

The computation of SCR is based on the following risk modules: (a) non-life underwriting risk; (b) life underwriting risk; (c) health underwriting risk; (d) market risk; (e) counterparty default risk. Each of these risk modules is calibrated using a Value-at-Risk.

The capital requirement for market risk is by far the most important risk module.[23] The regulation stresses in particular that the market risk module "shall properly reflect the structural mismatch between assets and liabilities, in particular with respect to the duration".[24] Appendix A.2.2 includes detailed information on the market risk module.

The stress on the duration miss-match between asset and liabilities owes to the nature of the insurance business. Insurance companies tend to have long duration liabilities. According to EIOPA, in 2020, the median duration for life insurance companies was 13 (22 for the 90$^{\text{th}}$ percentile) and 4 for non-life insurance companies (8 for the 90$^{\text{th}}$ percentile).[25]

Insurance companies also provide so-called unit-linked and index-linked policies. The main feature of these policies is that the policyholder bears the risk and are therefore not included in the computation of the capital ratios. If we exclude such policies, the lion's share of insurance liabilities are life-insurance policies (89%) rather than non-life insurance policies (11%).[26]

A.2.2 The market risk module

The market risk module[27] shall reflect the risk arising from the level or volatility of market prices of financial instruments which have an impact upon the value of the assets and liabilities of the undertaking. It shall properly reflect the structural mismatch between assets and liabilities, in particular with respect to the duration thereof.

[23] According to EIOPA 2022 Stress Test, the capital requirement for market risk accounts for 85.4% of the gross SCR before diversification benefits in the baseline.

[24] Source: Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II).

[25] Source: EIOPA Insurance Statistics

[26] We compute this ratio using the value of technical provision of the aggregate EU balance sheet provided by EIOPA for 2021.

[27] Source: Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II)

It shall be calculated, in accordance with point as a combination of the capital requirements for at least the following sub-modules:

(a) the sensitivity of the values of assets, liabilities and financial instruments to changes in the term structure of interest rates, or in the volatility of interest rates (interest rate risk);

(b) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of market prices of equities (equity risk);

(c) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of market prices of real estate (property risk);

(d) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of credit spreads over the risk-free interest rate term structure (spread risk);

(e) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of currency exchange rates (currency risk);

(f) additional risks to an insurance or reinsurance undertaking stemming either from lack of diversification in the asset portfolio or from large exposure to default risk by a single issuer of securities or a group of related issuers (market risk concentrations).

A.3 Pension Funds

The pension fund sector accounts for a total of 3.1tn at the end of 2021. The pension fund system in the Euro area is mostly pay-as-you-go (or notional defined contribution)[28], meaning that most of current pensions are funded by contributions from current workers. As a consequence, the total assets held by pensions are small. The only exception is Netherlands, whose pension fund sector's assets total 2tn (and hence more than two thirds of the total Euro area sector). Netherlands combine a pay-as-you-go system with a defined-benefit individual investment system, managed by pension funds. EIOPA is also in charged of the supervision of institutions for occupational retirement provision. The IORP II Directive sets common standards to protect pension scheme members and their beneficiaries. The directive also set rules on IORPs' own risk assessment. Differently from the insurance companies there are not a specific set of quantitative requirements.

A.4 Mutual Funds

The mutual fund sector (non-MMF investment funds) accounted for 17tn at the end of 2021. Mutual funds are regulated by the Undertakings for Collective Investments in Transferable Securities

[28] See OECD (2011)

(UCITS) Directive. Under the UCITS Directive funds have to comply with limits on balance sheet leverage, and borrowing should not exceed 10% of assets on a temporary basis. The UCITS Directive also imposes limit for synthetic leverage (which stems from derivative instruments or securities financing transactions), either through limits to the ratio of overall exposure with respect to NAV (Net Asset Value) or through limits to VaR (Value at Risk).[29]

Mutual funds in the Euro area are mostly held directly by households or by insurance companies and pension funds. However, some of the insurance investment fund holdings are connected to the unit-linked or index-linked policies aforementioned. In this case, as the policyholder bears the risk these can be considered as indirect household holdings. Using data from EIOPA, we calculate that approximately unit-linked and index-linked account for 47% of the total insurance companies mutual fund holdings.

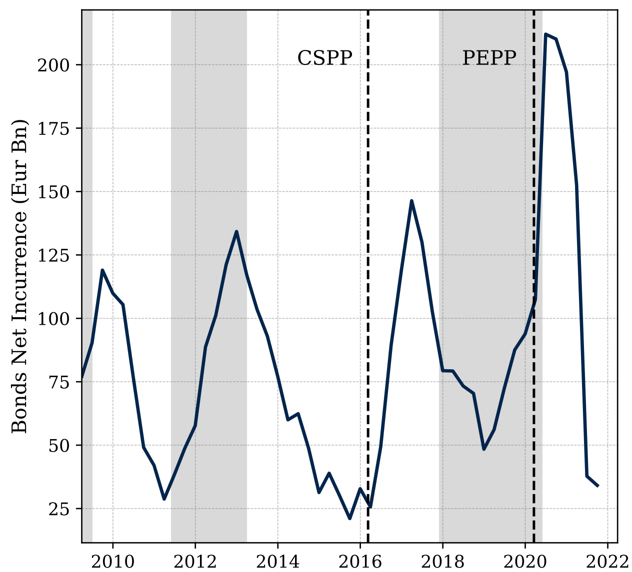
Table VIII: Holding Shares Mutual Funds

	2014	2019	2021
Households	0.34	0.31	0.33
Insurance Corp.	0.28	0.30	0.30
Pension Funds	0.17	0.19	0.16
Non-Financial Corp.	0.08	0.07	0.07
OFIs	0.03	0.04	0.06
Government	0.04	0.05	0.05
Banks and MMF	0.06	0.04	0.04

[29]See Doyle et al. (2016) for further details).

B. ECB and Corporate Bonds

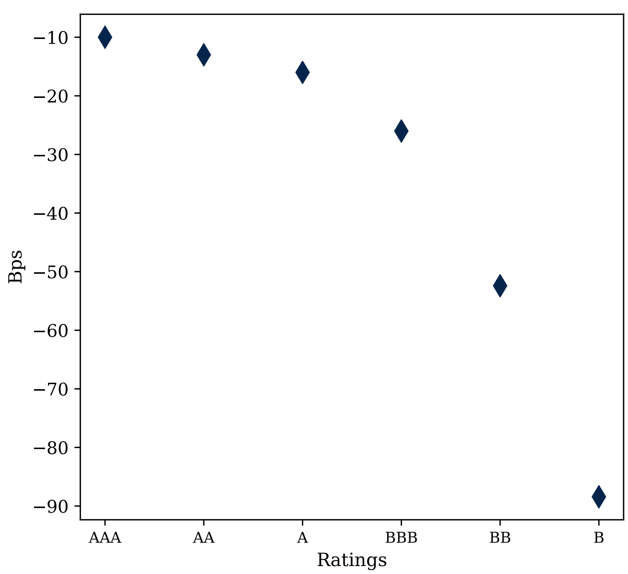
Figure 20: Corporate Bond Volumes, CSPP and PSPP



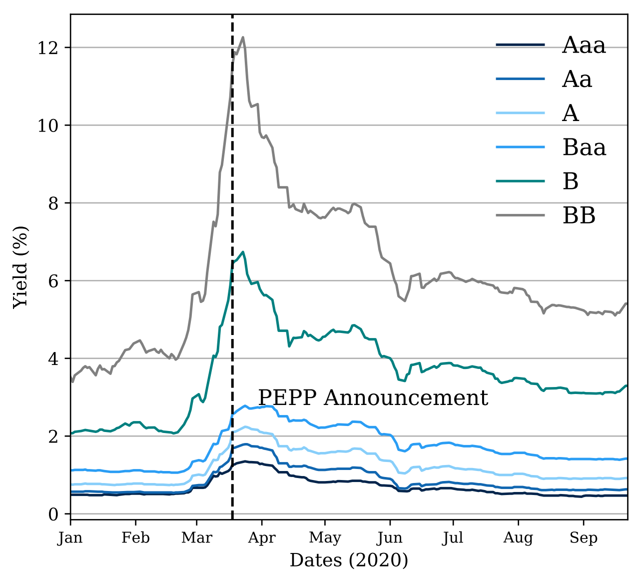
Note: The figure plots issuance of bonds by non-financial corporations. Source: Quarterly Sector Account.

Figure 21: Bloomberg-Barclays index, CSPP and PSPP, by Rating

(a) Response to CSPP, by Rating



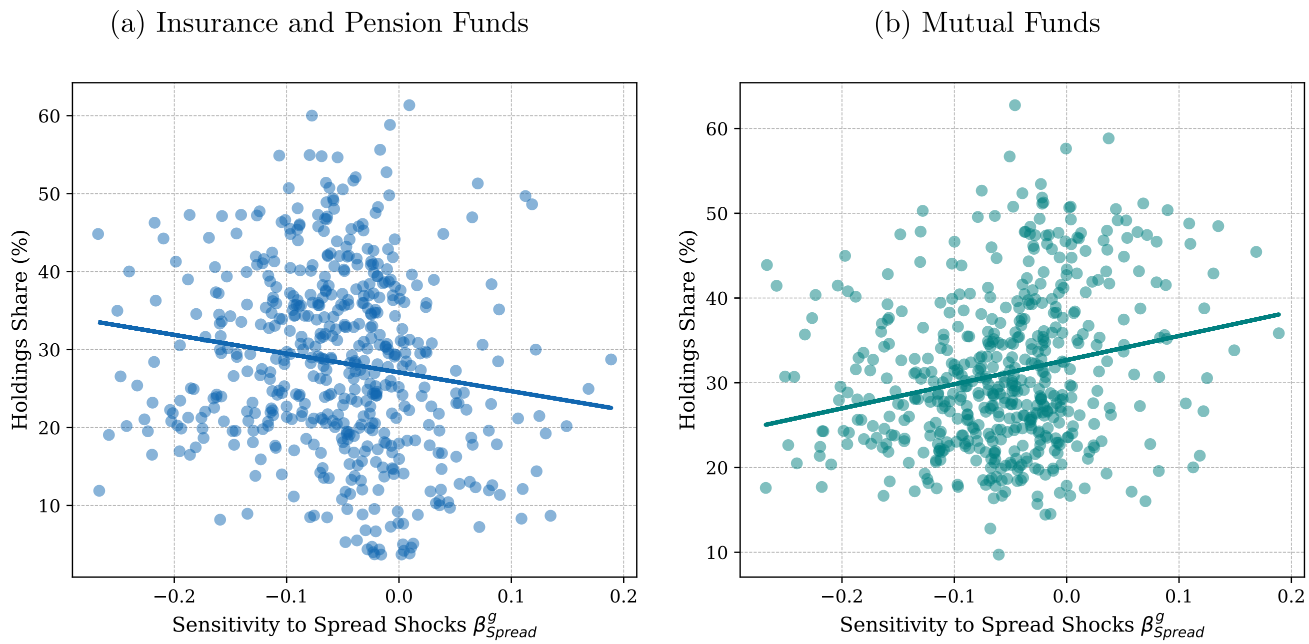
(b) PEPP Announcement, by Rating



Note: The figure plots the evolution of bonds around CSPP and PEPP announcements. Source: Bloomberg-Barclays.

C. Heterogeneous Sensitivity

Figure 22: Holding shares and Bond Sensitivity to Spread Shocks



Note: The figure plots the share held by different intermediaries and the sensitivity to spread shocks. Source: Markit iBoxx, ECB SHSS.

D. Drawdowns

Recent literature demonstrated that bonds held predominantly by domestic insurance companies rather than mutual funds suffer milder losses in crises. Coppola (2021) showed that during a downturn, mutual funds face withdrawals that push them to liquidate their positions and exacerbate the rise in bond yields. Coppola (2021) analysis mainly focused on the US but also present tentative evidence that similar mechanism holds in other countries, including the Euro area. We extend their analysis to our data to the Covid crisis. Compared to their analysis, we include detailed holdings by insurance companies, pension funds and banks. We analyze data in the first quarter of 2020, which saw a sharp rise in bond yields. We define drawdowns as the maximum variation experienced in bond yield spread in the quarter (maximum yield spread minus minimum yield spread). We then regress the drawdowns on the shares held by levered institutions or mutual funds, as in Equation 29. Table IX shows the results. We also find a sharper increase in spread for bonds held by mutual funds. Going from model 1 to model 7 we also find that the difference decreases, as part of the difference owes to selection rather than treatment.

$$Draw(ys_i) = \theta^{Lev} + \theta^{MF} + \text{Interacted Fixed Effects} + \varepsilon_i \tag{29}$$

Table IX confirms the finding of Coppola (2021), showing that

Table IX: Holdings and Covid Drawdown

	(1) Draw ys b/se	(2) Draw ys b/se	(3) Draw ys b/se	(4) Draw ys b/se	(5) Draw ys b/se	(6) Draw ys b/se	(7) Draw ys b/se
Levered	21.924	29.445	23.648	28.930	6.999	27.188*	0.175
	(22.16)	(22.96)	(32.47)	(18.46)	(17.29)	(13.96)	(5.70)
MF	178.570***	184.841***	148.305***	78.574***	44.905	84.086***	16.878**
	(26.87)	(33.82)	(32.29)	(27.01)	(30.92)	(27.79)	(7.04)
Observations	556	556	551	544	474	472	387
Adj. R-squared	0.086	0.082	0.182	0.503	0.635	0.725	0.964
Clustering		group	group	group	group	group	group
Fixed Effects	ISIN	ISIN	ISIN	ISIN	ISIN	ISIN	ISIN
Duration	No	Yes	Yes	Yes	Yes	Yes	Yes
Country	No	No	Yes	Yes	Yes	Yes	Yes
Rating	No	No	Yes	Yes	Yes	Yes	Yes
Rating Worst	No	No	No	Yes	Yes	Yes	Yes
Liquidity	No	No	No	No	Yes	No	No
Sector	No	No	No	No	No	Yes	Yes
Issuer	No	No	No	No	No	No	Yes

E. Additional Results

E.1 Variance Decomposition

In the previous sections, we provided evidence that ECB corporate bond purchases exert notable effects on bond yields and especially on the credit component. In Equation 1 we decompose the bond market yields into two components:

$$Y_t = \underbrace{Y_t^{IR}}_{\substack{\text{Interest Rate}\\ \text{Component}}} + \underbrace{Y_t^{CR}}_{\substack{\text{Credit Risk}\\ \text{Component}}} .$$

We then collect the list of regularly scheduled ECB governing council meeting from 2006 till 2021 and measure the variation in the two components around the ECB announcements. Define as $t = 1, ..T$ the day of each announcement. Further define $\Delta Y_{t-1,t+j}$ the variation from the day before to j-days after the announcement. There is a trade-off between taking a window which is too short (as the corporate bond prices may have not fully incorporated information) or windows that are too long (as many other events take places in the meanwhile). For this reason, we provide information using different lengths for the monetary policy window. We then conduct a variance decomposition of the changes in corporate bond yield index around ECB announcements:

$$Var(\Delta Y_{t-1,t+j}) = \underbrace{Var(\Delta Y^{IR}_{t-1,t+j})}_{\substack{\text{Interest Rate}\\ \text{Component}}} + \underbrace{Var(\Delta Y^{CR}_{t-1,t+j})}_{\substack{\text{Credit Risk}\\ \text{Component}}} + 2Cov(\Delta Y^{IR}_{t-1,t+j}, \Delta Y^{CR}_{t-1,t+j}).$$

We also select the list of announcements which conveyed information about the corporate sector purchases. Table X lists the main announcements related to the corporate sector purchases (CSP) from March 2016 onward. We call the announcements listed in the table corporate sector purchases (CSP) announcement, to distinguish for the rest of other ECB announcements (Non-CSP announcements). Information regarding the purchase programme – as well as other monetary policy measure – was also released in non-scheduled meetings. As discussed, the most notable of this example is the announcement related to the deployment of the Pandemic Emergency Purchase Programme (PEPP), announced on March 18, 2020 with a press release on the ECB website. In this exercise we only focus on the announcements held during the scheduled governing council (GC) meetings.

Table X: Announcements Related to Corporate Sector Purchases (CSP)

Date	Announcement
2016-03-10	Launched CSPP, extend APP to 80bn
2016-04-21	Press release with information on CSPP
2016-12-08	Extension of APP from April 2017 to Dec 2017 at 60
2017-10-26	Extend APP from January 2018 to September 2018 at 30 billion
2018-07-26	Reduce APP to 15bn until end of December 2018 and then end net purchases
2019-09-12	Restart APP at 20 billion
2020-03-12	Additional net asset purchases of 120 billion until the end of the year
2020-06-04	Increase the envelope for PEPP by 600bn to a total of 1,350bn
2020-12-10	Increase the envelope of PEPP by 500 bn to a total of 1,850bn
2021-12-16	Reduced the pace APP

Note: The table shows the list of the main ECB announcements with information regarding corporate bond purchases.

We then compute the variance of the interest rate component and the credit risk component on both the CSP announcements and the Non-CSP announcements. Table XI reports the i) variance of IR changes ($Var(\Delta Y^{IR}_{t-1,t+j})$) and CR changes ($Var(\Delta Y^{CR}_{t-1,t+j})$) on CSP announcements as well as Non-CSP announcements, ii) the ratio between the variance on CSP vis-à-vis Non-CSP announcements, iii) the ratio between the CS variance and IR variance on the two types of the announcements. We report results for different windows, from one day lag to three days lag ($j = 1, 2, 3$), in Panel a), b) and c), respectively. We also report results for different time periods: 2006-2021 and 2014-2021. Using the ratio between CSP and Non-CSP announcement days allow us to better compare standard announcement versus announcements on corporate bond asset purchases. It also lessens the concern related to the overall volatility of the two components: it may be that the different in variance on announcements reflect the fact that the CR component is in general more volatile than the IR component, or vice versa. different variance of IR and CR components. Taking the ratio of the variance allows us to isolate whether announcement on corporate purchases lead to different effects if compared to standard announcements. The results in Table XI confirms the suggestive evidence of Figure 4. If we take the full sample 2006-2021, for the two days lag, the variance ratio for IR is 0.39: that means that the variance on CSP announcement is roughly half of the variance on CSP announcement. For CS, the ratio is approximately 14. This means that CSP announcement seems to have strong effects on credit spread. The table also suggest that Non-CSP announcement has small effect on CR if compared to IR: the relative variance is 0.5. Instead on CSP announcement, the ratio of variance is close to 20. This means that overall we are observing larger effects on CR than IR even in absolute terms.

Table XI: CPS announcements: IR vs CS decomposition

	2006-2021			2014-2021		
Panel a) 1 day lag	IR	CR	Ratio CR/IR	IR	CR	Ratio CR/IR
Non-CSP	51.67	18.77	0.36	15.84	5.13	0.32
CSP	32.16	175.08	5.44	32.16	175.08	5.44
Ratio CSP/Non-CSP	0.62	9.33		2.03	34.11	
Panel b) 2 days lag	IR	CR	Ratio CR/IR	IR	CR	Ratio CR/IR
Non-CSP	75.17	41.87	0.56	14.87	10.07	0.68
CSP	29.38	580.54	19.76	29.38	580.54	19.76
Ratio CSP/Non-CSP	0.39	13.86		1.98	57.65	
Panel c) 3 days lag	IR	CR	Ratio CR/IR	IR	CR	Ratio CR/IR
Non-CSP	78.40	73.12	0.93	17.73	12.22	0.69
CSP	33.24	846.29	25.46	33.24	846.29	25.46
Ratio CSP/Non-CSP	0.42	11.57		1.87	69.27	

Note: The table shows the variance decomposition of the variation in bond yields around ECB announcement. Source: Markit iBoxx.

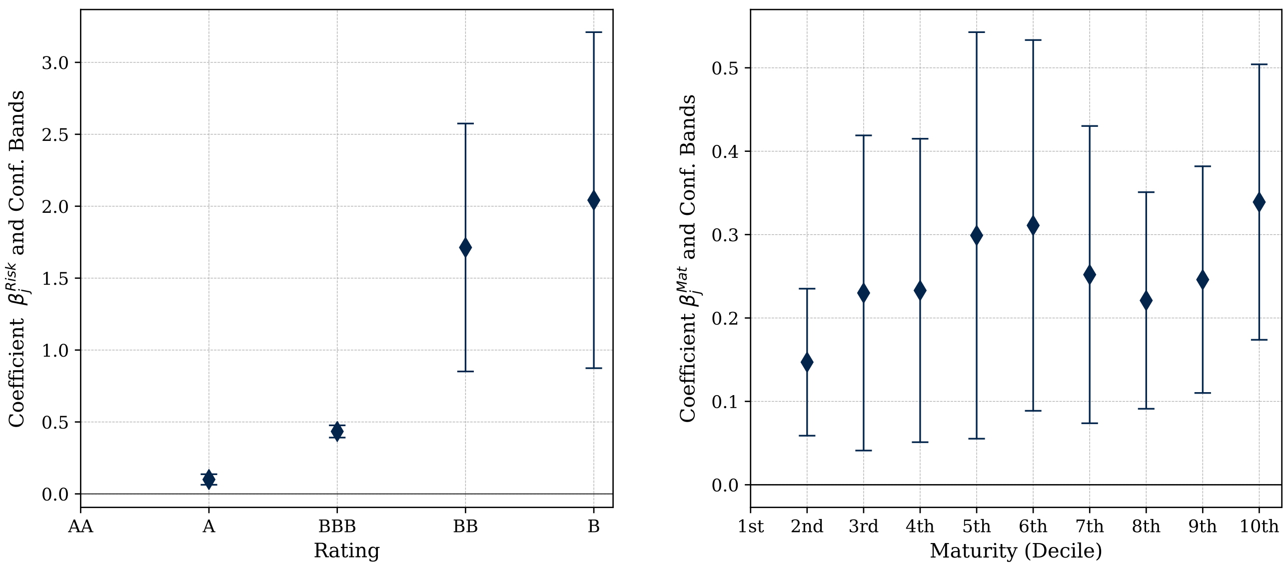
E.2 Sensitivity to credit spread Shocks by Ratings and Maturity

Figure 23 shows the results for Equation 28 where we used ratings instead of credit-risk deciles. The results in Figure 23a are broadly in line with our previous results.

Figure 23: Sensitivity to CR Shocks by Rating and Maturity

(a) Sensitivity to CR Shocks by Ratings

(b) Sensitivity to CR Shocks by Maturity Decile



Note: The figure shows the results of Equation 28. We divided bond based on their credit risk and maturity. We used ratings instead of credit-risk deciles. Figure 23a displayed the estimated β_j^{Risk} together with their confidence bands. Figure 23b display the estimated β_j^{Mat} together with their confidence bands. The sample runs from 2014 through 2021. The coefficients are estimated relative to the first riskiness and maturity group (for this reason, the coefficient for the first group are missing). Source: Markit iBoxx.

E.3 Mean-Variance Model

The model is two periods. There are multiple assets and two type of investors: a mutual fund and a levered intermediary.

Assets There is a risk-free bond B, that pays the gross risk-free rate R^f. There are J risky asset $j = 1, ...J$. They have exogenous dividends, with a factor structure:

$$d_j = \beta_j' F + u_j \tag{30}$$

where F is a vector of two factors: interest rate risk (F^{IR}) and credit risk (F^C). We assume that factors are not correlated and have variance σ_F. The expected value of factors are: μ_F. u_j

is the idiosyncratic risk of asset j. Lets define as $D = (d_1, ..d_J)$ the vector of dividends. sThe variance covariance of the vector D is Σ while the expected value is μ. The assets are supplied in amount θ.

We augment the set of risky asset with an additional asset L, that has also a dividend structure and it exposed only the interest rate risk factor:

$$d^L = \beta_L F^{IR} + u_L, \tag{31}$$

the expected value is μ^L and the variance is σ_L. The vector of covariance with the other assets is given by: Σ^L.

Mutual Funds The mutual mutual fund has mean-variance preferences. The budget constraint is:

$$N_{M,0} = P'X_M + B_M$$

where B_M is the amount of bonds. The future wealth is:

$$N_{M,1} = D'X_M + R_f(N_{M,0} - P'X_M)$$

The mutual fund problem is:

$$\max_{X_M} E[N_{M,1}] - \frac{\gamma}{2} Var(N_{M,1})$$

subject to the leverage constraint:

$$X'_M P \leq \chi^M N_{M,0}$$

The solution to the mutual fund problem is:

$$X_M = \frac{1}{\gamma}\Sigma^{-1}(\mu - R_f P - \lambda^M P)$$

Levered Intermediaries The levered intermediary has liabilities $P^L L$, where L is the number of units of debt and P^L is the price.

The levered intermediary budget constraint is:

$$N_{L,0} + P^L L = P'X_L + B$$

The net-worth next period is:

$$N_{l,1} = D'X_L + R_f(N_{L,0} + P^L L - P'X_L) - Ld^L$$

The levered intermediary problem is:

$$\max_{X_L} E[N_{L,1}] - \frac{\gamma}{2} Var(N_{L,1})$$

subject to the leverage constraint:

$$X_L' P \leq \chi^L (N_{L,0} + P^L L)$$

The levered intermediary take as given the price and quantity of liabilities (P_L, L). The levered intermediaries solve the lagrangian problem:

$$\begin{aligned}\max_{X_L} \mu' X_L + R_f(N_{L,0} + P^L L - P' X_L) - L\mu^L \\ -\frac{\gamma}{2}\left(X_L' \Sigma X_L + L\sigma_L - 2L X_L' \Sigma^L\right) \\ +\lambda_L(\chi^L(N_{L,0} + P^L L) - X_L' P)\end{aligned}$$

The optimal allocation is:

$$X_L = \frac{1}{\gamma}\Sigma^{-1}(\mu - R_f P - \lambda^L P) + L\Sigma^{-1}\Sigma^L$$

Households Households can only invest in the asset L or on the risk-free bonds. Households are only there to price the liability of the levered intermediaries. We assume they are also mean-variance optimizer with no leverage constraint and risk-aversion $\tilde{\gamma} = \frac{\gamma}{2}$.

Market Clearing By market clearing, the total demand for assets have to equate the total supply:

$$X_M + X_L = \theta$$

assuming that the levered intermediary take as given the price and quantity of liabilities (P_L, L). The equilibrium prices are:

$$P = \frac{1}{R^f + \tilde{\lambda}}\left(\mu - \tilde{\gamma}(\theta\Sigma - L\Sigma^L)\right)$$

where:

$$\tilde{\gamma} = \frac{\gamma}{2}$$

$$\tilde{\lambda} = \frac{\lambda^M + \lambda^L}{2}$$

Finally, we assume that households take the quantity of levered intermediary liability as given.

The equilibrium price for liability is hence:

$$P_L = \frac{1}{R^f}\left(\mu^L - \tilde{\gamma} L \sigma_L^2\right)$$

Hedgeability We find the optimal allocations to be:

$$X_M = \frac{1}{\gamma}\Sigma^{-1}(\mu - R_f P - \lambda^M P)$$

$$X_L = \frac{1}{\gamma}\Sigma^{-1}(\mu - R_f P - \lambda^L P) + \underbrace{L\Sigma^{-1}\Sigma^L}_{\substack{\text{Hedging}\\ \text{Demand}}}$$

The key difference is the Hedging Demand term. The terms command that levered intermediaries are going to tilt their portfolio allocation to assets that provide better hedging for their liabilities. If, the variance-covariance matrix was diagonal, the hedging demand term would be a vector with j entry:

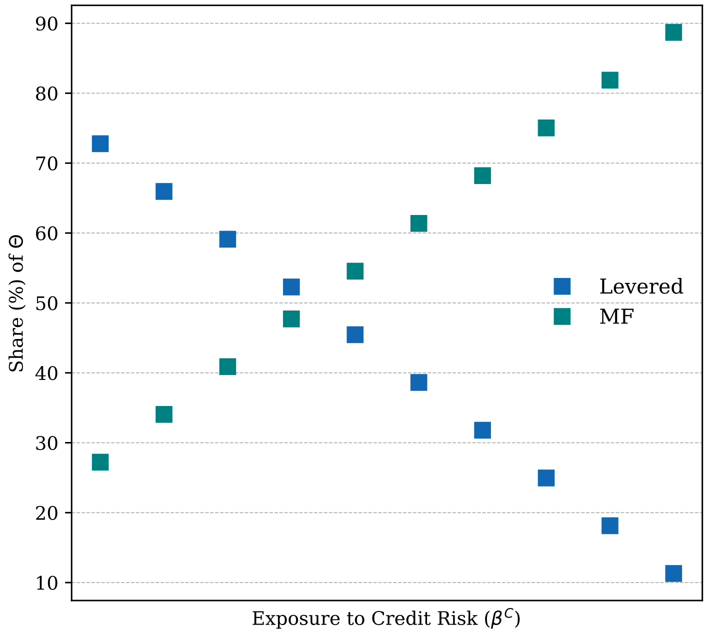
$$L\frac{Cov(d_j, d_L)}{Var(d_j)} \tag{32}$$

which is the covariance of asset j with the liability pay-off, divide by the riskiness of the asset.

E.4 Equilibrium Allocation with No Borrowing Constraints

Suppose that we have a set of securities j as with the same loadings on interest rate risk $\beta_j^{IR} = 1$, for each $j = 1, ..J$; the liabilities L also have $\beta_L^{IR} = 1$. We assume that asset differs by their exposure to credit risk: we allow for β_j^C to vary from 0.25 to 2. We then solve the model for 10 assets (matching to the 10 risk deciles described in Section **??**). Figure 24 plots the equilibrium allocations across assets. The figures shows that levered intermediaries are going to demand safer assets, driving up the prices and pushing mutual funds to rebalance into riskier assets.

Figure 24: Model: Allocation by Credti Risk



E.5 Empirical Measure of Hedgeability

We estimate empirically the hedgeability coefficient, described in Equation 24. We use the full set of investment grade corporate bonds. We sort bonds based on their risk. We then compute monthly returns on each bond portfolio. We also use data on the Euribor Swap curve to measure the risk-free returns. As insurance companies measure their liabilities using the Swap curve, the returns on swap are a good measure of the variation in valuation of insurance companies assets.

The hedgeability coefficient can then be measured as a linear regression:

$$R_t^L = \alpha + \beta^{Hed} R_{i,t} + \varepsilon_t \tag{33}$$

where R_t^L are the returns on swap. $R_{i,t}$ are the returns on our sorted bond portfolios. In fact:

$$\beta^{Hed} = \frac{Cov(R_t^L, R_{i,t})}{Var(R_{i,t})}$$

We evaluate the regression 33 on our data. The results are displayed in Figure 25.

Figure 25: Empirical Hedgeability Measure