



# Bilan des banques centrales et stabilité financière

Maëlle Vaille

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THESE PRESENTEE

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ECOLE DOCTORALE ENTREPRISE, ECONOMIE ET SOCIETE (ED 42), SPECIALITE  
SCIENCES ECONOMIQUES

Par **Maëlle Vaille**

**BILAN DES BANQUES CENTRALES ET STABILITÉ  
FINANCIÈRE**

Sous la direction de **Stéphane DEES** (Banque de France), Maître de Conférences HDR  
et de **Michel DUPUY**, Professeur des Universités

Soutenue le 18 octobre 2023

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# General Introduction

In March 2023, the Federal Reserve (Fed) has once again demonstrated « *the immense power of its balance sheet* »<sup>1</sup>, while it responded quickly to the failures of Silicon Valley Bank (SVB) and Signature Bank by creating a new lender of last resort facility, the Bank Term Funding Program (BTFP), to preserve financial stability. This program allows banks to exchange financial assets such as U.S. Treasuries for cash at their full-face amount, regardless of the current market value. This surge in emergency lending through the BTFP and the Fed Discount Window unwound nearly half of its balance sheet contraction started in June 2022, through its Quantitative Tightening (QT) policy. After peaking at nearly USD 9 trillion in June 2022, overall Fed's holdings had fallen to USD 8.34 trillion on March 8, 2023 before moving up to USD 8.7 trillion on March 22. However, the temporary increase in the Fed balance sheet did not call into question the restrictive nature of monetary policy. Fed responded to specific increases in money demand exchanging less-liquid assets for more liquid ones, while the pace of QT remained unchanged. Thus, the Fed has over again proved its flexibility in using its balance sheet as a monetary policy tool, and the huge power of this instrument to safeguard financial stability, i.e. the resilience of the financial system to withstanding shocks and the unravelling of financial imbalances.

In the broadest sense, balance sheet policies can be viewed as any balance sheet action taken by the central bank that attempts to affect asset market conditions beyond adjusting a short-term interest rate (Borio and Disyatat, 2010). This includes foreign exchange intervention, long-term lending programs and asset purchases programs.<sup>2</sup> These measures can be implemented for the purposes of both macroeconomic and financial stability. This thesis will focus solely on the effects of these policies on financial stability. The central bank's use of its balance sheet has played a

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<sup>1</sup>Orphanides, Athanasios, Fiscal Implications of Central Bank Balance Sheet Policies (July 8, 2016). MIT Sloan Research Paper No. 5168-16, Available at SSRN: <https://ssrn.com/abstract=2807249> or <http://dx.doi.org/10.2139/ssrn.2807249>

<sup>2</sup>In this thesis, we will mainly focus on the last two types of balance sheet policies as exchange rate policy is linked to specific objectives relating to the evolution of the country's currency.

significant role in financial history, well before the global financial crisis of 2007-2008, as reminded by Ricardo Reis (« *The central bank's balance sheet has always been a policy tool... The use of quantitative easing and other unconventional tools in the recent past has just made us study these issues better, learn more about their effects, and so become more confident about using them in the present and in the future.* », Centre for Macroeconomics survey in 2016). According to Thornton (1802)<sup>3</sup> and Bagehot (1873)<sup>4</sup>, during times of financial distress, only the central bank could be a credible lender of last resort (LLR), thanks to its ability to create monetary liabilities which could be used to provide liquid assets to banks in difficulty. In this classical version, LLR policy works through bilateral lending by the central bank to illiquid but solvent private institutions, against good collateral. Bagehot also advocated lending at a penalty rate to discourage all but those truly in need from applying and to limit the expansion in liquidity to the minimum necessary to end the panic. LLR interventions have played a key role of central banks for centuries, with an increasing central banks' sensitivity to financial crises over the 20th century. In the 1800s and early 1900s, Bagehot and his LLR policies were effectively applied in several countries. In the United-Kingdom, the failure of the Overend Gurney Company in 1866 led the central bank to apply the Bagehot's Rule "to lend freely but at a penalty rate". It prevented incipient financial crises in 1878, 1890, and 1914 from developing into full-blown panics by timely announcements and action. In the United-States, the banking crisis of 1884 led the Clearing Houses of New York, Chicago, and other central reserve cities to issue emergency reserve currency in the form of clearing house loan certificates collateralized by member banks' assets. In France, appropriate actions by the Banque de France in 1882, 1889, and 1930' prevented nascent banking crises from developing into panics. Similar behavior occurred in Germany in 1901 and 1931 and in Canada in 1907 and 1914. The Bank of Japan (BoJ) actively played the role of LLR by providing emergency loans to private banks in the 1920s when the Japanese financial system became unstable.

While LLR may have been primarily focused on banks refinancing, there are also historical precedents for central banks stepping in to restore broader market functioning at critical moments. In

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<sup>3</sup>Thornton, Henry, « An Enquiry into the Nature and Effects of the Paper Credit of Great Britain » (1802). YPFS Documents (Series 1). 14247

<sup>4</sup>Bagehot, Walter, 1873. «Lombard Street: A Description of the Money Market,» History of Economic Thought Books, McMaster University Archive for the History of Economic Thought, number bagehot, 1873.

September 1939, the Fed purchased USD 800 millions of U.S. Treasury securities to (i) buffer the price decline due to Britain's suspension of golds payments and (ii) maintain an orderly market. Two other similar interventions took place in 1958 (following a regime change in government funding arrangements) and 1970 (amidst unrest over the Vietnam war). Thus, even the asset purchase programs set up in the wake of the 2007-2008 financial crisis are not 21st century inventions.

Central bank balance sheet policies, as part of the monetary policy toolkit, came back into the spotlight (i) following the financial crisis in Japan during the 1990s, and even more so (ii) following the global financial crisis of 2007-2008. The latter was the catalyst to the large-scale adoption of balance sheet policies in developed and emerging economies.

In the late 1990s and early 2000s, the Japanese economy was facing slowing demand, declining consumer prices, and financial instability due to a confluence of factors. After implementing the Zero Interest Rate Policy (ZIRP)<sup>5</sup>, the BoJ has initiated the Quantitative Easing Policy (QEP). The new policy strategy entailed a change in policy instrument, from the short-term rate to quantity of reserves, and purchases of long-term Japanese Government Bond (JGBs) to increase the monetary base. In addition, the BoJ took specific steps to target pockets of financial vulnerability, including widening the range of acceptable collateral for its fund providing operations and allowing banks to sell stocks directly to the BoJ. Japan's long experience of balance sheet policies provided valuable lessons to other central banks a decade later.

In the wake of the global financial crisis of 2007-2008, most of the central banks took a radical and creative approach, both in terms of the modalities and the objectives of their instruments. They showed commendable skill in using their balance sheets to prevent what could have been an even worse financial crisis, similar to the BOJ a decade earlier. When the conventional monetary policy responses were ineffective and not sufficient, central banks turned to non traditional monetary policy tools in exercising and extending their function of lender of last resort, and achieving their inflation target. More precisely, central banks rapidly reduced their key interest rates close to zero in order to (i) stabilise the financial system, (ii) counter deflation expectations and (iii) mitigate the

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<sup>5</sup>Monetary policy maintaining nominal short-term interest rates at zero.

looming deep recession. With policy rates close to their effective lower bound<sup>6</sup>, and the impairment of transmission of short-term interest rates to the economy's financing conditions, central banks introduced major innovations in terms of their operational framework, following the recommendations of Bernanke and Reinhart (2004). To stimulate aggregate demand in a low-interest-rate environment, the two authors recommended to (i) alter the composition of central bank's balance sheet, to affect the relative supply of securities held by the public, influence term premiums<sup>7</sup> and thus overall yields and (ii) expand the size of the central bank's balance sheet, as increases in money supply lead investors to rebalance their portfolios and modify their expectations about policy rates. Thus, together with the forward guidance<sup>8</sup>, the explicit and active calibration of the size and composition of the central bank balance sheet became one of the main monetary policy instrument. Central banks have been found to greatly deviate from the traditional doctrine of LLR since the global financial crisis of 2007-2008, the characteristics of a modern LLR including the provision of liquidity and collateral, loosening collateral standards, supporting critical institutions, opening special liquidity facilities that target specific markets or groups of agents, becoming market maker of last resort<sup>9</sup> and buyer of last resort.

From an operational perspective, the speed and size of the balance sheet policies implemented were unprecedented, yet as a policy response, it was not unique. Central banks' lending programmes focused on alleviating funding market tensions by providing counterparties with access to liquidity. Considering the ineffectiveness associated with the traditional LLR tool, central banks have modified some of their existing loan programs, by accepting a wider range of collateral, broad-

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<sup>6</sup>«The rate below which it becomes profitable for financial institutions to exchange central bank reserves for cash», De Fiore, Fiorella & Tristani, Oreste, 2018. «(Un)conventional policy and the effective lower bound», Working Paper Series 2183, European Central Bank.

<sup>7</sup>The term premium is defined as the compensation demanded for holding long bonds. It can depend on both the amount of risk and the price of that risk, either of which can change over time due to variable fundamentals (see Don H Kim & Athanasios Orphanides, 2007. «The bond market term premium: what is it, and how can we measure it?», «BIS Quarterly Review, Bank for International Settlements, June for more details.

<sup>8</sup>Tool used by the central bank to provide indications about its monetary policy intentions

<sup>9</sup>This function of market make of last resort can be fulfilled in two ways: (i) through open market operations in a much wider range of financial instruments, especially private sector securities, than central banks normally are willing to trade in, (ii) by accepting illiquid private securities as collateral for repos and at the discount window, which requires the central bank to establish a valuation of these securities.

ening the set of eligible counterparties, conducting “fixed rate full allotment”<sup>10</sup> credit operations, increasing the frequency of certain operations. For example, the Federal Reserve opened the Term Auction Facility (TAF) in December 2007 to allow banks to borrow liquidity in groups and pledge wider than at the discount window range of collateral. In March 2008, the Fed created the Primary Dealer Credit Facility (PDCF) and extend the eligible collaterals to include unsecured, illiquid and privately issued securities which could be considered as against Bagehot’s criteria of “secure collateral”. What completely contradicts Bagehot’s LLR criteria is the Fed’s direct support to specific and insolvent financial institutions. For example, The Fed basically financed the nationalization of American International Group (AIG) by providing a Revolving Credit Facility loan of USD 85 billion in exchange for the transfer of 80 per cent of AIG’s equity to the Treasury held by the AIG Credit Facility Trust. Regarding the ECB, the central bank has engaged in unlimited longer-term refinancing operations (LTROs) in 2009. The ECB also actively lowered its already lax collateral standards, including assets that have been downgraded by ratings agencies, such as peripheral sovereign debt. In addition, some of its lending programmes had the objective of providing additional monetary stimulus, by providing incentives to institutions to extend credit to targeted sectors of the real economy (i.e Targeted Long Term Refinancing Operations<sup>11</sup>). The differences in the scope of the extended LLR operations between the Fed and the ECB can be associated with the different market structures. Europe have more bank-based rather than market-based financial systems of Anglo-Saxon countries like the United-States. While deviating in modalities, this new version of LLR policies remain consistent with the overall objectives laid down by Bagehot (1873). Through asset purchases programmes (or Quantitative Easing), central banks have used their balance sheet as an additional and a last resort sort of tool to (i) trigger economic recovery (traditional transmission channels being impaired) and (ii) address the deterioration in financial markets functioning. The Fed and the ECB use open market operations to buy longer-term rather than short-term maturity securities as part of their quantitative easing strategies. They use these traditional operations in a much wider range of financial instruments, especially private sector securities,

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<sup>10</sup>Counterparties have their bids fully satisfied, against adequate collateral, and on the condition of financial soundness.

<sup>11</sup>If a bank under the TLTRO programme increased lending to firms and households above a certain threshold, the interest rate could actually be cut below zero (down to -0.40% for TLTRO II).

than central banks normally are willing to trade in. The increase in the central bank's holdings of bonds and other securities are funded by an increase in its liabilities, usually commercial banks' reserve balances. The financial crisis led the Federal Reserve to conduct several asset purchases programmes (Quantitative Easing): QE1 (2008), QE2 (2010), Operation Twist (2011), QE3 (2012). The ECB initiated its asset purchases programs later, with the first created in July 2009 (Covered Bond Purchase Programme), but the real ECB's quantitative easing began in 2015 with the creation of the Asset Purchases Programmes (APP) including several programmes (PSPP, CBPP3, CSPP, ABSPP). The global outbreak of the Covid-19 pandemic in early 2020 led central banks to expand their balance sheets substantially once again. On 18 March 2020 the ECB launched a €750 billion Pandemic Emergency Purchase Programme (PEPP), covering public and private securities. Similarly, on 23 March 2020, the Fed announced that it would purchase unlimited amounts of U.S. Treasury and mortgage-backed securities.

As a result of these two types of balance sheet policies, the balance sheets of the Fed and those of the ECB had respectively growing by respectively 17% and 13%, annualized, between 2008 and mid-2022.

While these central bank balance sheet policies helped to prevent calamitous financial implications in the short term, their prolonged use (more than a decade) is not without risks and may have unintended consequences for financial stability.

First of all, there is no doubt about the positive impact on financial markets. A consensus has emerged about the sizeable empirical effects of balance sheet policies on long-term yields and other asset prices<sup>12</sup>, and their ability to address short-term financial stability risks. For example, the provision of liquidity to banks and the purchase of specific assets mitigates financial market's instability and vulnerabilities in the banking sector. Indeed, these policies lead to low interest rate which reduce bank funding costs, and to higher asset prices which have a positive effect of valuation. Banks can also take advantage of lower long-term rates to extend the maturity of their debt

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<sup>12</sup>Wright (2012) finds that unconventional monetary policy shocks have a large effect on 10-year Treasury yields. Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), D'Amico and King (2013) find that asset purchases programmes were successful at flattening the yield curve in the United-States.



and reduce the maturity mismatches (Lambert and Ueda, 2014). Moreover, the macroeconomic objective of balance sheet policies indirectly improve financial stability. Indeed, by encouraging economic activity, these measures can help strengthen private and public balance sheets. Balance sheet policies also have a positive effect on financial stability by preventing a worsening of market functioning. For example, in response to the interbank market freeze in 2008, the provision of central bank liquidity strengthened the confidence of investors and depositors, helping banks' regain funding access, and also improving functioning in other markets.

However, more recently, the debate has also evolved towards the risks and side effects potentially associated with balance sheet policies in place for a prolonged period of time. Central bankers mentioned this issue in various speeches: « *I share concerns about the potential side-effects of balance-sheet policies that pose risks to financial stability and threaten the central bank's independence* », Esther George (Kansas City Federal Reserve Bank President) in 2019<sup>13</sup>, or « *Because these non-conventional tools raise the potential for a buildup in financial vulnerabilities and imbalances, monetary policymakers need to expend extra effort in assessing financial stability risks* », Loretta J. Mester (President of the Federal Reserve Bank of Cleveland) in 2021<sup>14</sup>. The potential side effects of balance sheet policies on financial stability was also one of the themes addressed in the ECB Forum on Central Banking in 2020. This issue has become paramount due to the fact that these tools have over the years become an integral part of the toolkit of many central banks. While one of the aim of central banks' balance sheet policies is to cope with short-term risks to financial stability when conventional measures are ineffective, there are potential medium and long-term concerns arising from such a significant shift in the size and composition of central bank balance sheets. First, a persistent flattening of the yield curve can put pressure on bank profitability and on pension funds and life insurance companies' financial health, slowing down their recapitalization. The later can also be delayed due to the ample bank liquidity that may raise credit risk at banks by compromising underwriting and loan quality standards. Second, a protracted period of low interest rates and abundant liquidity may over time induce excessive risk-taking by financial institutions.

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<sup>13</sup>Price Stability: A Main Street Perspective, National Association for Business Economics in Denver, Colorado, U.S. October 6, 2019.

<sup>14</sup>Financial Stability and Monetary Policy in a Low-Interest-Rate Environment, Speech at the Workshop on Low-Interest-Rate and Unconventional Monetary Policy Norges Bank, Oslo, Norway, June 22 2021

This behavior can be reinforced by the increase in moral hazard due to the fact that financial investors systematically expect the central bank to intervene whenever asset valuations collapse. An excessive search for yield can (i) help push the market value of assets beyond their fundamental value and lead to asset price bubbles, and (ii) drive an excessive increase in financial institutions' balance sheet leverage. Moreover, balance sheet policies can make financial institutions depending on central bank liquidity, hindering restoration of private sources of funding. Therefore, while central bank balance sheet policies lead to the mitigation of financial instability in the short-run, they may affect market functioning and create financial vulnerabilities over the longer term. While it is clear that monetary policymakers need to be aware of financial stability risks, a less settled question is how monetary policymakers should best address emerging financial stability risks, especially when taking actions to promote monetary policy goals might be in conflict with containing financial stability risks.

Because the private sector has become so dependent on the central bank, the contractionary effect of the unwinding of central bank balance sheet can also threaten the financial stability (Acharya, Chauhan, et al. 2022). There are many uncertainties surrounding the process of reducing the balance sheet: « *I would just stress how uncertain the effect is of shrinking the balance sheet* » (Jerome Powell, May 2022<sup>15</sup>), « *How quantitative tightening operates in practice, however, is highly uncertain* » (Isabel Schnabel, March 2023<sup>16</sup>). Since inflation reached levels well above the 2% target in 2022, central banks have embarked on the quest of shrinking their large balance sheets by selling securities or letting them mature and disappear from their books. Quantitative tightening by the largest central banks will withdraw USD 2 trillion in liquidity out of the financial system over the next two years, according to a recent analysis by Fitch Ratings in February 2023.<sup>17</sup> This normalization process could pose challenges for financial stability. First, quantitative tightening could add pressure on Treasury market liquidity. Net issuance of the U.S. Treasury securities is projected to

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<sup>15</sup>Federal Open Market Committee, May 4, 2022

<sup>16</sup>Quantitative tightening: rationale and market impact, Speech at the Money Market Contact Group meeting, Frankfurt am Main, 2 March 2023

<sup>17</sup><https://www.fitchratings.com/research/sovereigns/global-quantitative-tightening-will-be-usd2trn-over-next-two-years-23-02-2023>

increase in 2023 and 2024, while the share absorbed by the Fed is reducing. Private sector will need to absorb more short- and medium-term securities. A lack of liquidity in what is considered one of the most liquid markets would severely hamper the stability of the financial system. Second, there is a risk of capital losses on fixed-rate securities for banks and other financial institutions. Indeed, the exit of expansionary balance sheet policies lead to increasing interest rates, especially the term premium component, which translates into a repricing of the bond market. While a rise in interest rates improves the profitability over time, losses on fixed- rate securities available for sale are immediate. In the short term, weakly capitalized banks could suffer. Finally, as quantitative tightening leads to the decline of banks reserves, funding rates could increase markedly as market participants compete for increasingly scarce pools of liquidity in the open market.<sup>18</sup> This disintermediation of interbank liquidity by the central bank would have to be offset by a revival of private interbank markets. If this market is not fully restored, some banks could face funding challenges. Despite all of these concerns, there is scant empirical analysis of the broad financial market effects of unwinding the central bank's balance sheet.

The purpose of this thesis is to determine the financial stability effects of balance sheet policies. While one of the main objectives of these measures is to preserve financial stability in the short term, what about the possible side effects of the prolonged use of these instruments on financial stability? What about the potential market distortions caused by this massive provision of liquidity? Moreover, is a smooth exit from these balance sheet policies possible?

Given the importance of this challenges for central bankers, three lines of research had been covered, following the evolution in the main concerns of central bankers regarding the use of their balance sheets. First, the thesis focuses on **the extent to which the financial stability has been affected by changes in central bank's balance sheet since 2008 for the ECB and the Fed and the early 2000s for the BoJ**. Taking into account the relevance of the composition of central banks' balance sheet, the second line of investigation looks into **the differences in the**

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<sup>18</sup>As seen in September 2019 in the United-States.

**effect of public assets purchases programs from more risky ones on the financial markets.** Finally, in light of the new monetary policy environment of monetary policy since 2022, the last line investigates **whether balance sheet's unwinding affect financial asset prices and financial stability metrics at the time of their announcements.** To answer these questions, the thesis is organised into three parts.

In the first chapter, we empirically investigate if the balance sheet policies implemented since 2008 for the United-States and the euro area and since the early 2000s for Japan created financial instability. We evaluate the overall effect of exogenous innovations to the central banks' balance sheet on two financial stability indicators, (i) a measure of systemic risk in the banking system (the SRISK) and (ii) a measure of equity market overvaluation (sign of instability on financial markets), within a structural BVAR model. In a second step, we revisit the relationship between central bank balance sheet policies and systemic risk by adopting a firm-level approach. The objectives are to verify if we find similar results at a disaggregated level and also to study the possible heterogeneous effects of balance sheet shocks on financial firms' SRISK. This second aim is linked to the literature relative to monetary policy transmission and financial institutions' heterogeneity. Our main result is that these policies seem to support financial stability in the short and medium term in line with their objective, and even in the long-term for Japan. The firm-level approach confirms this finding, but highlights the heterogeneity between financial institutions. Balance sheet shocks reduces systemic risk more for the financial institutions with the highest level of financial leverage. If the global effect of central bank balance sheet shocks since 2008 seems positive for financial stability according to the results of our first chapter, the story should be different if we now distinguish between the various balance-sheet policies. To which type of monetary policy should we attribute the effect on financial stability? The new monetary policy instruments affect financial stability through a few distinct transmission channels. It is then obvious that they act differently on financial stability measures. Moreover, the literature systematically treats asset purchase programs as a whole, but it is important to distinguish the effects of these policies according to the nature and the risk of the financial securities purchased.

The second chapter attempts to determine the effect of each monetary policy measures on financial stability, keeping the same financial stability indicators as in chapter 1. The main objective is therefore to disentangle the different monetary policy shocks: asset purchase programs, forward guidance and conventional monetary policy. The major contribution of this work is to propose a new decomposition of monetary policy surprises by disentangling quantitative easing (QE) programmes related to public asset purchases from those implying more risky assets.

Following Gürkaynak et al. (2005), and Altavilla et al. (2019), we apply principal component analysis to the changes in various market interest rates at the time of the ECB and Fed policy announcements in order to extract factors that explain most of the variation of these rates around the chosen time window. Using a sign restriction approach applied to factor identification, we add the following restriction to disentangle private assets purchases programmes from public ones: public QE should lead to an increase in corporate bonds spread while private QE should have negative effects on corporate bonds spread (its impact on private bonds being larger than on government ones). Then, we estimate impulse responses by Smooth Local Projections (SLP) in order to assess the impact of monetary policy surprises on the SRISK and our measure of equity market overvaluation. We find some differences in the effect of public QE and private QE on our two financial instability indicators. As expected, private asset purchase programs contribute more to financial system vulnerabilities than public ones. However, in the longer run, the effects of the two types of QE become insignificant, meaning that regardless of the nature and risk of the securities purchased, these measures do not seem to have persistent side effects on financial stability. Moreover, confirming previous findings, when considering the two other factors (target and forward guidance), expansionary surprises also lead to a temporary rise of systemic risk-taking and contribute to asset price overvaluation. Overall, our chapter therefore confirms the presence of financial stability side effects due to the use of unconventional monetary policy tools by central banks, but these effects are temporary and do not represent a durable threat to financial stability.

If the literature has focused on the unintended and side effects of QE due to its extended use, wouldn't it ultimately be the withdrawal of this policy that could destabilize the markets?

The final chapter, written during the shift from an ultra-accommodative policy to a restrictive one, explores the effects of Fed’s quantitative tightening announcements on financial asset prices and financial stability metrics, based on the 2017-2019 experience and the second balance sheet unwinding which has been in place since June 2022. Our first innovation is to compare the reaction of our financial variables to three types of policy events: (i) QE, (ii) tapering and (iii) QT announcements. Our second contribution is to study the reaction of all asset classes (i.e. fixed-income, equities, forex, commodities) and financial stability measures to central bank’s balance sheet communication. The objective is to have an overall vision of financial markets’ reaction to QT announcements. Do these three types of balance sheet policies induce price readjustments at the time of their announcement? If so, do the price changes concern only the assets concerned by the announcement (Treasuries and Mortgage-backed security<sup>19</sup>) or do these changes extend to all asset classes? The literature often limits to the response of Treasuries and corporate bond yields to monetary policy announcements. However, when we study the short-term reaction of financial markets to policy announcements, all asset prices may be subject to significant movements. Is the communication around them destabilizing and stressing investors? Or on the contrary, have investors already readjusted their prices beforehand?

Our findings show strong asymmetries in the reaction of financial markets to balance sheet expansions, normalisation and unwinds. QE and tapering events lead to strong variations in the price of all asset classes, while QT announcements had been fully anticipated by the market participants, as intended by the Fed. The strong revaluations of financial assets following QE announcements was the Fed’s objective for QE, which used its communication to change market expectations and thus influence asset prices. The communication around tapering was, on the other hand, a monetary policy mistake, and has led the Fed to review the way it communicates this kind of policy. Our second main result is that none of these measures lead to financial instability at the time of their announcements, except QT which affects the liquidity of the Treasury market. This finding is consistent with the fact that QT drains liquidity from markets by removing a guaranteed

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<sup>19</sup>A type of asset-backed security which is secured by a mortgage or collection of mortgages.

buyer of massive amounts of debt securities. Thereby, despite asset price adjustments ahead of the announcements, liquidity in this market seems to be under stress following the announcements, as demonstrated by the bid-ask spread reaction. Moreover, the lack of financial markets effects around QT communication does not guarantee that this measure will not lead to disruptions in the markets as it is implemented.

# CHAPTER 1

## Central bank balance sheet & systemic risk<sup>20</sup>

*« By becoming the “only game in town” and using their discretionary powers, central banks revealed the immense power of their balance sheet. » (Orphanides, 2016)*

### 1 Introduction

The global financial crisis led central banks to expand their balance sheet on an unprecedented scale, as a result of implementing various unconventional monetary policy operations. As policy rate was close to its effective lower bound (ELB), balance-sheet policies (BSP) have become the primary monetary policy instruments to stimulate the economy and prevent renewed financial tensions. More than ten years later, central banks are still using their balance sheet as an active tool of monetary policy and the recent turmoil implied by the Covid-19 crisis has led to a further expansion in asset purchasing and lending programs in order to address financial market strains and provide policy stimulus. The literature on central bank balance sheet policies has surged following the financial crisis, most papers focusing on how effective the BSP was in supporting financial stability and economic activity (Motto, Altavilla, and Carboni 2015). However, there is still uncertainty about the magnitude of these effects and, more importantly, about the mechanisms through which

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<sup>20</sup>This Chapter is under revision for the Quarterly Review of Economics and Finance.  
The chapter has been selected for the Young economist’s competition of the European Central Bank in 2021.  
[https://www.ecb.europa.eu/pub/conferences/ecbforum/previous\\_fora/2021/html/YEcompetition2021.en.html](https://www.ecb.europa.eu/pub/conferences/ecbforum/previous_fora/2021/html/YEcompetition2021.en.html)



these policies operate. From an empirical perspective, identifying a causal effect of balance sheet policies is challenging, as they are usually implemented in response to economic events, thereby creating an endogeneity problem. More recently, the debate on BSPs has shifted to the associated risks and side effects that these measures could trigger if left in place for a prolonged period. While one of the aim of central banks' BSP is to cope with short-term risks to financial stability when conventional measures are ineffective, there are also possible medium and long-term concerns arising from such a significant shift in the size and composition of central bank balance sheets. While the nature of the different financial stability risks can be demonstrated, they are extremely hard to quantify and to identify in which time frame could materialize. Balance sheet policies can adversely affect financial stability via different transmission channels. First, a persistent flattening of the yield curve can put pressure on bank profits and on pension funds and life insurance companies' financial health, slowing down their recapitalization. Second, a protracted period of low interest rates and abundant liquidity may over time induce excessive risk-taking by financial intermediaries. This behavior can be reinforced by the increase in moral hazard due to the fact that financial investors systematically expect the central bank to intervene whenever asset valuations collapse. Finally, balance sheet policies, especially large-scale asset purchases, may lead to the emergence of financial asset price misalignments. On the other hand, there are serious arguments for maintaining permanently central bank balance sheet as a monetary policy tool, in particular to meet a financial stability objective. The most compelling and mentioned argument in favor of this has been made by Greenwood, Hanson, and Stein (2018) who emphasize that there is a strong demand from the private sector for safe, liquid, short-term securities, and that central banks are in a unique position to offer such assets.

In this paper, we evaluate the overall effect of exogenous innovations to the central banks' balance sheet on the aggregate SRISK indicator in the euro area, the United States and Japan. We complete our main analysis by looking at the effect of balance sheet size variations on a measure of market equity overvaluation, in order to broaden our focus on financial stability. The SRISK (V. Acharya et al. 2017; Brownlees and R. Engle 2012) has proven to be relevant and provides fair

early warning signals of on-going financial distress (Colletaz, Levieuge, and Popescu 2018). At the individual level, it can be defined as "the expected capital shortfall of a given financial institution, conditional on a crisis affecting the whole financial system" (Benoit, Colliard, et al. 2017). In its aggregated version, this indicator corresponds to the total amount of capital that would be needed to bail out the financial system if a financial crisis were to occur (Colletaz, Levieuge, and Popescu 2018). According to Colletaz, Levieuge, and Popescu (2018), this measure presents various advantages such as its theoretical foundations, the facts that it can be computed using publicly available data and that the SRISK can predict which institutions are going to be confronted with losses during a financial crisis. Macroeconomic studies relative to the risk-taking channel are very scarce. In line with the paper of Colletaz, Levieuge, and Popescu (2018) which study the causality between conventional monetary policy (CMP) and the SRISK indicator in the euro area, we decide to fill this gap by analyzing the effects of BSP-related shocks on the SRISK indicator in the euro area, the United States and Japan. Regarding our measure of equity market overvaluation, we follow the methodology of Blot, Hubert, and Labondance (2020a) and use a factor model to summarize the information on three different approaches - (i) structural, (ii) data-driven and (iii) statistical - to identify asset prices imbalances. The underlying assumption is that the first principal component of the three models would capture their common denominator and therefore constitute a reliable indicator of asset price bubbles.

We use a structural bayesian vector autoregression (BVAR) model over the period September 2008 to December 2018 for the euro area and the United States and January 2000 to March 2018 for Japan. As a proxy for balance sheet policies, which included lending programmes and asset purchase programmes, we use the central bank total assets' growth which is one of the most used proxy in the literature (Altunbas, Gambacorta, and Marques-Ibanez 2014; Boeckx, Dossche, and Peersman 2017; Kremer 2016; Burriel and Galesi 2018; Gambetti and Musso 2020). The main empirical challenge for our study, as in any empirical analysis of the effects of BSP, is the endogeneity issue. Central bank balance sheet fluctuations are a combination of changes in monetary policy that could be interpreted as exogenous, and an endogenous response to (i) developments in the economy and (ii) financial turbulence. To isolate central bank balance sheet shocks, we use a mixture of zero and

sign restrictions, currently used in this literature (Boeckx, Dossche, and Peersman 2017; Kremer 2016; Altunbas, Gambacorta, and Marques-Ibanez 2014).

In a second step, our analysis is extended to financial firms' level estimations using panel bayesian VARs to study the effects of balance sheet shocks on financial institutions' systemic risk and to highlight the role of financial leverage in the transmission of BSP to the SRISK of financial firms taken individually. We no longer use the aggregated SRISK but the SRISK of the financial institutions. Moreover, we control for the size and the risk of the financial institutions by adding three control variables in our model: financial leverage, market capitalisation and LRMES (Long-Run Marginal Expected Shortfall). This additional analysis is relevant because the aggregate approach does not take into account the possible heterogeneity of the effects of monetary policy shocks. The evidence of risk-taking behaviours at the microeconomic level does not necessarily imply significant macroeconomic effects (Colletaz, Levieuge, and Popescu 2018; Brissimis and Delis 2010). This part relies on the literature on the importance of the financial institutions' business model in the transmission of monetary policy to systemic risk (Brissimis and Delis 2010; Delis and Kouretas 2011; Ricci 2015; Lamers et al. 2019).

Our results suggest that balance sheet policies have beneficial effects on the aggregate systemic risk at the short and medium term. In the longer run, we find no significant effects, which means that increasing the size of central banks' balance sheet does not appear to have an adverse effect on financial stability. By contrast, conventional monetary policy shocks lead in the short term to an increase in systemic risk in the euro area and have no effect in the United States and in Japan. At a disaggregated level, we find similar results: BSP shocks lead to an improvement in financial stability. Moreover, we highlight the role of financial leverage in the transmission of BSP to financial firms' systemic risk: high leverage institutions are those for which SRISK decreases the most following BSP shocks.

The remainder of this paper is organized as follows. Section II describes central bank balance sheet policies and the literature relative to the effects of such policies on financial stability. Sec-

tion III presents empirical results of our structural BVAR model on the impact of balance sheet policies on systemic risk and on our measure of market equity overvaluation. Given these findings, in section IV, we embark into checking whether we find similar results at a financial firms' level. Section V concludes.

## **2 Central bank balance sheet policies and financial stability**

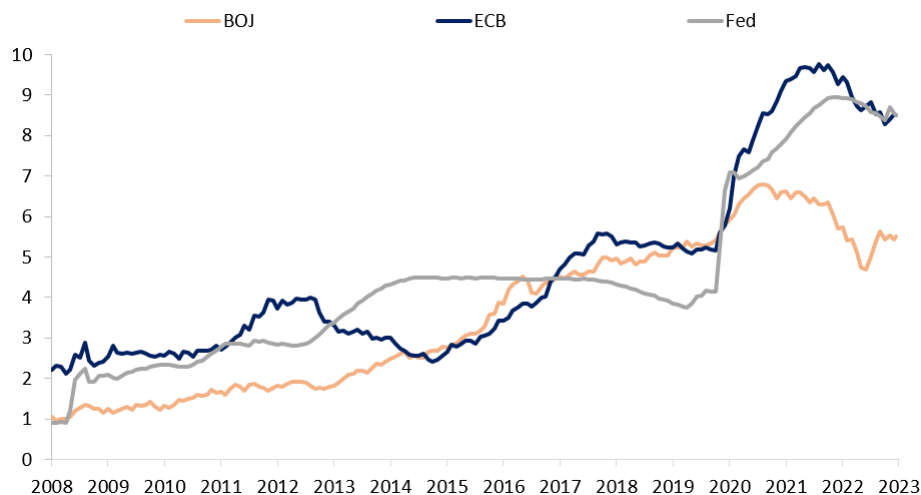
Central banks' balance sheet has significantly expanded since the global financial crisis of 2007-2008. This phenomenon has been driven by the need to influence financial conditions beyond the short-term policy rate by adjusting the size and/or the composition of their balance sheet. Balance sheet policies include (i) large-scale asset purchases programmes and (ii) the supply of central bank funding at non-standard terms and conditions. While the immediate financial stability effects of these measures have been positive in terms of providing new liquidity, resolving dysfunctional financial markets and reducing uncertainty, several observers have raised concerns with regard to the build-up of new financial stability risks stemming from such policies. There is no consensus about possible unintended side effects of those unconventional measures on financial markets among academics (Lamers et al. 2019).

### **2.1 Central bank balance sheet policies**

Our paper focuses on the European Central Bank (ECB), the Federal Reserve of United States (Fed) and the Bank of Japan (BoJ). Besides the BoJ, which had already used the size of its balance sheet as a monetary policy instrument (in response to the banking crisis of the end of 1990s), the balance sheets of the Fed and the ECB recorded a sizeable expansion in the second half of 2008 (see figure 1). The size of the ECB balance sheet has increased more than fourfold, and those of the Bank of Japan (BoJ) and the U.S. Federal Reserve (FED) by a factor of about six and eight respectively from 2007 to 2020. This change has been driven by lending to banks and asset purchase programmes (see tables 1 and 2 below) aimed at stabilising financial markets as well as promoting growth and employment. Lending programmes were designed to alleviate severe tensions in the interbank money market and to affect credit conditions by providing ample liquidity to banks and other

financial institutions. Central banks created new, or extended existing lending facilities to provide ample liquidity to financial institutions, under considerably looser conditions (mostly by allowing lower-quality collateral), for longer horizons (from weeks to years), and possibly at a lower cost. The ECB started in 2008 to provide unlimited funding to banks, conducting its refinancing operations as fixed rate full allotment tenders (FRFA), widened the range of assets eligible as collateral to allow more flexibility for banks to obtain loans from the ECB and extended the term maturity of the LTROs from three to six months. In 2011, the ECB introduced the very long term refinancing operations (VLTROs) and launched between 2014 and 2019 three programmes of targeted long term refinancing operations (TLRO I, TLRO II, TLRO III). The principle of the TLTRO's is that the amount that banks can borrow from the ECB is linked to their loans to non-financial corporations and households. In the U.S, in December 2007, the Fed introduced the Term Auction Facility (TAF), the Term Securities Lending Facility (TSLF), and the Primary Dealer Credit Facility (PDCF), to support the market segments with severe liquidity shortages. Finally, in Japan, the BoJ introduced the Special Funds-Supplying Operations to Facilitate Corporate Financing in December 2008, which provided unlimited amounts up to the total collateral value. The BoJ also introduced fixed rate funds-supplying operations at a three-month maturity in December 2009 and at a six-month maturity in August 2010.

Figure 1: Central bank total assets (BOJ, ECB & Fed) in U.S Dollar



Notes: Total Assets as of 12.05.2023 (trillion dollars, nsa, weekly, ratio scale)

The second category of balance sheet policies, asset purchase programmes, aims at lowering borrowing costs for the real economy mostly by reducing the returns and the associated risk premia of the assets purchased. Central banks began quantitative easing by purchasing government bonds. To a lesser extent, their programmes included other securities, such as mortgage-backed securities (MBS) in the United States or investment grade corporate bonds in the euro area or even equities in Japan. In the euro area, in March 2015, the ECB launched its asset purchase programme (APP), wherein it purchased both sovereign bonds of euro area countries and private-sector securities. Purchases initially totalled 60bn of euro per month, rising to 80bn of euro per month in April 2016 before reverting to 60bn of euro per month in April 2017. In October 2017, the ECB announced that it would scale back these purchases to 30bn of euro per month as from January 2018, and that it would continue these purchases until the end of September 2018, or beyond, if necessary. At the same time, the ECB committed to "reinvest the principal payments from maturing securities purchased under the APP for an extended period of time after the end of its net asset purchases"; this means that the Eurosystem's balance sheet will remain quite large in the years ahead. Between 2008 and 2014, the Fed implemented three successive QE programmes (QE1, QE2, QE3). In late 2014, it halted its net asset purchases, stating that the economic recovery was robust enough for it to withdraw this supporting factor. Therefore, between late 2014 and September 2017, the Fed maintained its balance sheet at a steady level by reinvesting the proceeds from maturing assets into new asset purchases. In October 2017, the Fed started to run down its balance sheet. In Japan, the BoJ began in 2001 to purchase Japanese government bonds (JGBs) and asset-backed securities (ABS) to boost reserves. Since 2013, the BOJ moved strongly to counter persistently sluggish economic activity with "Quantitative and Qualitative Easing" (QQE) that used open-ended, contingent asset purchases to increase the size and maturity of the BOJ's assets. In September 2016, the BOJ responded with "QQE with Yield Curve Control" that targeted both the overnight deposit rate and the 10-year JGB yield at -0.1 percent and 0.0 percent, respectively. The BOJ thus became the only central bank to explicitly target long-dated yields. This expansion of central bank's balance sheet, through asset purchase programs, is an "asset driven" one. On the liabilities side, this increase in central banks' assets mainly corresponded to an increase in financial institution

deposits. Table 1 and 2 resume the balance sheet policies of the three central banks during our study period.

The Covid-19 epidemic also recently prompted renewed lender-of-last resort interventions and asset purchases by central banks in order to ensure a smooth functioning of the financial system and facilitate the flow of credit to households and firms. Unlike the other central banks, the Fed has announced that it will conduct an open-ended purchase program, buying Treasuries and agency mortgage-backed securities. The Fed is buying assets unusually fast compared with past purchase episodes: Treasuries purchases peaked at \$75 billion in late March 2020 before settling into the recent pace of \$15 billion per day, which is much quicker than the peak pace of \$120 billion per month during the previous financial crisis. The Fed established for the first time purchase programmes for assets issued by municipal entities and local public authorities. In the euro area, the ECB expanded its ongoing Asset Purchase Programme (APP) by committing to purchase an additional 120 billion of euro in private and public assets by end-2020. Later, it allocated 1.35 trillion of euro to private and public asset purchases under the newly established Pandemic Emergency Purchase Programme (PEPP). In Japan, the BOJ likewise increased its Japanese government bond (JGB) purchases to an 80 trillion yen annual pace, increased commercial paper and corporate bond purchases, and doubled the pace of purchases of exchange-traded funds (ETFs) and Japanese real estate investment trusts (J-REITs). Regarding lending policies, the ECB has expanded its TLTRO III by two thirds and reduced its costs to create incentives for banks to lend to businesses and households. It also introduced additional Pandemic Emergency Longer-Term Refinancing Operations (PELTROs) to provide banks with long-term funds irrespective of their lending pattern. The Fed and BoJ increased the amount of repurchase agreements offered and lengthened their maturity. The Fed also encouraged the use of its discount window and intervened to prevent funding strains for primary dealers, by lending against investment grade debt, and for money market mutual funds, by lending to depository institutions against assets purchased from those funds. Also, the Fed and BoJ established targeted lending programmes designed to provide funds to banks at favourable terms, conditional on loan extension to small and medium-sized enterprises (SMEs). The Fed

reactivated the TALF to support the issuance of asset-backed securities. It also established the Paycheck Protection Program Liquidity Facility (PPPLF) to provide liquidity against payroll loans guaranteed by the Treasury. The scope and speed of the international central bank policy response to COVID-19 has met or often exceeded that of the 2007-09 crisis. The Fed or the ECB are staying away, for now, from ETFs while purchasing various sorts of assets under their untraditional monetary policies. The BOJ is, for now, the only central bank purchasing stocks through ETFs, which is one of the distinctive characteristics of the BOJ's untraditional monetary policy. The BOJ buys stocks via ETFs to promote more risk-taking activity in the overall economy by lowering the risk premium of asset prices and reducing the cost of the equity capital of Japanese companies.

In this paper, we choose to focus on the overall effects of balance sheet policies, i.e. the increase in the size of central bank balance sheet. These instruments work through different transmission channels. The first is the interest rate channel: as borrowing rates fall, credit expands either directly through financial markets or via a bank lending channel. The second one is the signaling channel which consists for the central bank to promise to maintain a loosening monetary policy stance by expanding its balance sheet. However, it is important to underline that these two policies, i.e. asset purchase programmes and lending programmes, may have different effects on financial stability via their own transmission channels. Indeed, asset purchase programmes may affect financial stability via premium, duration, rebalancing portfolio channels while bank lending may impact it via favorable financing conditions and bank lending channel.

## 2.2 Literature survey

A large body of literature exists on the effects of balance sheet measures on financial variables (yield curve, exchange rates, financial asset prices), with a very short-term perspective, using the event-study methodology (Krishnamurthy and Vissing-Jorgensen 2011; D'Amico and King 2013). There is a broad consensus that these policies lead to a drop in long-term yields and a boost in asset prices (Gürkaynak, B. Sack, and E. Swanson 2005; Joyce, Miles, et al. 2012). However, there remains high uncertainty about the size and the nature of the impact of these instruments on financial stability indicators in the medium and long run. Given the evidence that balance sheet



Table 1: Overview of ECB, Fed and BoJ main asset purchases programmes

<b>ECB</b>	Covered Bond Purchase Programme I (05/2009)
	Securities Market Programme (05/2010)
	Covered Bond Purchase Programme I (10/2011)
	Asset-backed Securities Purchase Programme (09/2014)
	Covered Bond Purchase Programme II (10/2014)
	Public Sector Purchase Programme (03/2015)
	Corporate Sector Purchase Programme (03/2016)
	Pandemic Emergency Purchase Programme (03/2020)
<b>Fed</b>	Large-Scale Asset Purchases I - Agency Debt (11/2008)
	Large-Scale Asset Purchases I - MBS (11/2008)
	Large-Scale Asset Purchases I - Treasuries (03/2009)
	Large-Scale Asset Purchases II - Treasuries (11/2010)
	Maturity Extension Programme (09/2011)
	Large-Scale Asset Purchases III - Agency MBS (09/2012)
	Large-Scale Asset Purchases III - Treasuries (12/2012)
<b>BoJ</b>	Commercial Paper Purchase (01/2009)
	Corporate Bond Purchase (02/2009)
	Comprehensive Monetary Easing (10/2010)
	Quantitative and Qualitative Easing (04/2013)
	Quantitative and Qualitative Easing with Yield Curve Control (09/2016)

policies have had significant effects on financial variables through their announcement effects, we explicitly choose to exclude these effects and focus on the medium and long-term effects of changes in the balance sheet size.

Among the narrow segment of literature concerned with the long-term effects of these policies on financial stability, two competing views emerge. Greenwood, Hanson, and Stein (2018), whose paper had great resonance at the 2016 Jackson Hole conference, argue for retaining a large central bank balance sheet to control financial stability risks. More precisely, these authors claim that the Fed should use its balance sheet by supplying safe assets to lean against private sector maturity transformation. Reducing the scarcity of safe assets also reduces the incentives for financial intermediaries to fund on a short-term basis. The literature about the supply of safe assets to enhance financial stability has been surveyed by Golec and Perotti (2017). This argument is for now less relevant in the case of the euro area and Japan because of their predominantly bank-based nature financial system. Nevertheless, the structural changes (the increased role of secured money market transactions, the importance of a broad set of market rates beyond the overnight rate, the growing

Table 2: Overview of ECB, Fed and BoJ main lending programmes

<b>ECB</b>	Fixed rate full allotment (08/2007), LTRO / VLTRO (12/2011), TLTRO (09/2014), TLTRO II (06/2016), TLTRO III (09/2019), PELTRO (04/2020)
<b>Fed</b>	Term Auction Facility (12/2007), Primary dealer credit facility (03/2008), Term Securities Lending Facility (03/2008), Asset-Backed Commercial Paper Money Market Fund Liquidity Facility (09/2008), Commercial Paper Funding Facility (10/2008)
<b>BoJ</b>	Commercial Paper repo (10/2008), Fixed rate funds (10/2008), Special funds corporate financing (12/2009), Fund-provisioning measure to facilitate strengthening of the foundations for economic growth (12/2008), Loan support programme (12/2012)

relevance of non-bank institutions in market-based finance, the scarcity of safe assets that affects the functioning of markets) are also growing in the euro area and in Japan and it is important to reflect on the possible limitations of monetary policy transmission by only influencing the very short end of money-market rates (See Constâncio Vítor, 2016<sup>21</sup>). On the theoretical side, Woodford (2016) finds a positive impact of asset purchase programmes on financial stability through a monetary equilibrium model that simultaneously examines the effects of the central bank's balance sheet on financial conditions and how the financing decisions of private banks can increase risks to financial stability. He demonstrates that this BSP allows for greater financial stability through a reduction in the equilibrium risk premium. Indeed, this reduction in the spread between the expected return on risky assets and the risk-free rate leads to a reduction in the purchase of risky assets, which de facto reduces the overall systemic risk. He finds that quantitative easing increases the supply of reserves/Tbills, reduces (i) the net supply of long-term assets, (ii) the safety premium, and (iii) the desire of private sector to do maturity transformation.

Opposite findings were put forward, for example, by Lewis and Roth (2019). By using a VAR model, the authors show that ECB's asset purchase programs increase market volatility, liquidity risk and contagion risk putting therefore financial stability in danger. More recently, V. V. Acharya et al. (2023) demonstrate that during balance sheet expansion, commercial banks (i) financed reserve holdings with deposits, (ii) reduced their average maturity, (iii) issued lines of credit to corporations. However, when the Fed halted its balance-sheet expansion and even reversed it

<sup>21</sup>"The challenge of low real interest rates for monetary policy", Lecture by Mr Vítor Constâncio, Vice-President of the European Central Bank, at the Macroeconomics Symposium, Utrecht School of Economics, Utrecht, 15 June 2016

during quantitative tightening, there was no commensurate shrinkage of these claims on liquidity. Consequently, reserve issuance may elicit an endogenous bank response that may make the system more, rather than less, prone to liquidity risk and threaten the financial stability.

When looking at the effect of monetary policy on financial stability, most studies focus on the risk-taking channel (Borio and Zhu 2008; Adrian and Shin 2008; Jiménez, Lopez, and Saurina 2013; Dell’ariccia, Laeven, and Suarez 2017). The risk-taking channel operates in two ways. First, low returns on investments may increase incentives for banks, asset managers and insurance companies to take on more risk for contractual or institutional reasons. Excessive risk-taking is especially relevant to institutions, such as insurance companies, with commitments to streams of fixed future payments (Rajan 2005). Second, low interest rates affect valuations, incomes and cash flows, which in turn can modify how banks measure risk (Gambacorta 2009). The effects of balance sheet policies on risk-taking or search for yield are more ambiguous. There are several transmission channels that can have contradictory effects. Furthermore, encouraging more risk-taking, and thereby more lending, was a key aim of BSP, and therefore more risk-taking should be regarded as a success of monetary policy (Claeys and Darvas 2015). It is excessive risk-taking, because of distorted incentives, that can lead to financial instability. Financial firms may take on additional risk and leverage because of the flattening yield curve and the cut in the term premium. At the same time, balance sheet policies may have positive valuation and liquidity effects (Brana, Campmas, and Lapteacru 2019; Delis, Hasan, and Mylonidis 2017). More precisely, Lamers et al. (2019) identify four channels through which BSP can affect bank stability. First, asset purchases flatten the yield curve and reduce banks’ returns on maturity transformation and credit risk and consequently decrease banks’ net interest margins which may affect bank profitability negatively. Second, loosening of monetary policy tend to boost asset prices and can be considered as a stealth recapitalization channel (Brunnermeier and Sannikov 2014). Third, lending programs of central banks lead to an alleviation of funding risk for banks and hence higher bank profitability. The fourth channel is the forbearance channel: improving profitability and funding stability may allow banks to postpone cleaning up their balance sheets by writing off non-performing loans. Regarding the main findings

in this literature, Chodorow-Reich (2014) found that for insurance companies and bank holding companies, stock prices rose and spreads on credit default swaps fell immediately following the announcements of large-scale asset purchases. He attributed this to an improvement in the value of the assets already on the institutions' books, which lessened solvency concerns (K. Kuttner 2018). Focusing on banks, Kurtzman, Luck, and Zimmermann (2017) attributed the increased lending to the improvement in the banks' capital positions and not to the QE1 and QE3. Other transmission channels are listed. For example, protracted suppression of volatility due to unconventional measures typically fosters undue leverage through endogenous market dynamics, such as "collateral amplification", creates a false sense of the robustness of conventional statistical risk metrics and may even impair investment professionals' personal resilience in the face market distress. Among this area of research on risk-taking, some authors have studied the effects of monetary policy, especially conventional monetary policy, on metrics of systemic risk. Faia and Karau (2019) use a fixed effects panel VAR model and find that exogenous increase in the interest rate leads to a significant drop of CoVar<sup>22</sup> (Adrian and Brunnermeier 2016) and LRMES<sup>23</sup> (Brownlees and R. Engle 2012). Lamers et al. (2019) assess the impact of monetary shocks on bank systemic risk, approximated by LRMES, using a panel regression framework. They find that accommodative policy generally has a positive effect on bank stability in the euro area due to a stealth recapitalization channel but a negative effect in the United States due to risk-shifting. The empirical evidence of the risk-taking channel mainly relies on micro studies. However, some authors adopt a macroeconomic perspective. Colletaz, Levieuge, and Popescu (2018) study the causality between conventional monetary policy and the SRISK indicator in the euro area. Deev and Hodula (2016) also point to increased risk for financial stability if central banks' balance sheet remains at their current levels. Based on a TVP-SVAR model to account for variations in the size of monetary policy shocks, they investigate the effects of monetary policy on systemic risk in the euro area, distinguishing pre and post-crisis periods. Their analysis suggests that BSP, approximated by the aggregate M2, leads to undesired outcomes and aggravates financial instability in euro area countries (approximated by the aggregate

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<sup>22</sup>The change in the value at risk of the financial system conditional on an institution being under distress relative to its median state.

<sup>23</sup>The expected fractional loss of the firm equity in a crisis when the S&P 500 Composite Index declines significantly in a six-month period.

SRISK).

Overall, it is difficult to draw conclusions about the impact of BSP on financial stability. First, there are several unconventional tools that may have different effects on financial stability. Moreover, there are different transmission channels of these measures to the real sphere but also to the financial sphere, so there may be contradictory effects for the same tool. This is compounded by the complexity of estimating the effects and identifying monetary policy shocks.

### 3 The empirical approach

#### 3.1 Structural BVAR model

In this section, we assess the impact of balance sheet measures on the SRISK indicator in the euro area, the United States and Japan, by adopting a macroeconomic approach. The idea is that while these instruments seem to have served their purpose in the short term, unanticipated adverse effects on financial stability may emerge in the medium and long term. The empirical model adopted to undertake this analysis is represented by a structural BVAR model<sup>24</sup>. We consider a time series dataset at a monthly frequency which ranges from September 2008 to December 2018 for the euro area and the United States and from January 2000 to March 2018 for Japan<sup>25</sup>. The short time period makes it necessary to choose monthly observations in order to have sufficient information available to estimate the structural BVAR model. Our empirical strategy is related to the VAR studies of Altunbas, Gambacorta, and Marques-Ibanez (2014), Boeckx, Dossche, and Peersman (2017), Gambetti and Musso (2020) and Weale and Tomasz Wieladek (2016) who investigate the macroeconomic effects of the balance sheet policies. The VAR allows us to model the effects of shocks dynamically, while imposing only a minimum set of assumptions about the structure of the economy. We use a Bayesian approach as it accounts for estimation uncertainty due to our partial identification with the methodology of sign and zero restrictions (Jarociński and Karadi 2018). The

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<sup>24</sup>We use the Bayesian Estimation, Analysis and Regression (BEAR) toolbox by Dieppe, Roye, and Legrand (2016) for the estimation of the models.

<sup>25</sup>We start the analysis in September 2008 for the U.S. and for the EA, the month that marks the start of the increase in their balance sheet size. For Japan, we start in 2000 for reasons of data availability.

structural VAR model that we consider has the following representation:

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + C + B \epsilon_t \quad (1)$$

where  $Y_t$  is the vector of endogenous variables,  $A_0$  is the matrix of contemporaneous influences,  $A_p$  is the matrix of influences at lag  $p$  and  $\epsilon_t$  is a vector of (uncorrelated) structural shocks, normally distributed with mean 0 and variance  $I_k(0, 1)$ . The starting point for estimating the structural model is to assume that  $A_0$  is invertible and express the model in its reduced form:

$$Y_t = \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + \dots + \theta_p Y_{t-p} + C + B u_t \quad (2)$$

where:

$$\theta_p = A_0^{-1} A_p \quad (3)$$

$$u_t = A_0^{-1} \epsilon_t \quad (4)$$

$$E(u_t u_t') = \Omega = E(A_0^{-1} \epsilon_t \epsilon_t' A_0'^{-1}) = A_0^{-1} I_k A_0'^{-1} \quad (5)$$

In a Bayesian procedure, the parameters are treated as random variables and their posterior distribution is estimated via the imposition of prior beliefs on their distribution. The prior and posterior distributions of the reduced-form VAR belong to the Normal-Wishart family. It allows, compared to the Minnesota prior, to relax the assumption that the residual covariance matrix  $B$  is known. The Normal-Wishart distribution assumes that the matrix containing VAR coefficients  $A_p$  is multivariate normal:

$$A_p \sim N(A_{p_0}, \Omega_0) \quad (6)$$

where coefficient mean  $A_{p_0}$  is an  $m \times 1$  vector and  $\Omega_0$  is an  $m \times m$  diagonal coefficient covariance matrix with variance relating endogenous variables to their own lags given by:

$$\delta_{ii}^2 = \left( \frac{\lambda_1}{I \lambda_3} \right)^2 \quad (7)$$

where  $\lambda_1$  is a hyper-parameter that controls the overall tightness,  $I$  is the lag considered by the

coefficient and  $\lambda_3$  controls the relative tightness of the variance of lags other than the first one. The variance for cross-variable lag coefficients is given by:

$$\delta_{ij}^2 = \left( \frac{\delta_i^2}{\delta_j^2} \right) \left( \frac{\lambda_1 \lambda_2}{I \lambda_3} \right)^2 \quad (8)$$

where  $\delta_i^2$  and  $\delta_j^2$  denote the OLS residual variances of an autoregressive model estimated for variables  $i$  and  $j$  and  $\lambda_2$  is a hyper-parameter that controls the cross-variable weighting. Finally, the variance for the constant is given by:

$$\delta_c^2 = \delta_i^2 (\lambda_1 \lambda_4)^2 \quad (9)$$

where  $\lambda_4$  is a hyper-parameter governing the exogenous variable tightness. We specify the prior using standard values for the hyper-parameters following Dieppe, Roye, and Legrand (2016), i.e. we set the AR coefficient of the prior to 0.8, overall tightness  $\lambda_1 = 0.1$ , cross-variable weighting  $\lambda_2 = 0.5$ , lag decay  $\lambda_3 = 1$  and exogenous variable tightness  $\lambda_4 = 100^{26}$ . All variables of the model deviate from their stationary state, which removes any cointegration problems.

The vector of endogenous variables  $Y_t$  contains three variables included in all standard monetary policy VARs of the literature: (i) the log of the consumer price index, (ii) the log of the industrial production index and (iii) a short-term interest rate measuring the stance of conventional monetary policy (EONIA for the euro area, Tibor for Japan and the effective Federal funds rate for the United States). These core model variables are complemented by two additional endogenous variables: (i) the log differences of central bank total assets as in order to control for potential additive seasonality in the data and remove the upward drift in the log levels of these serie (Kremer 2016), and (ii) the aggregate SRISK measure as a proxy for financial instability (Colletaz, Levieuge, and Popescu 2018). We obtain historical data on macroeconomic variables essentially from Datastream. Aggregated SRISK indicator was provided us by the Volatility Institute (V-Lab) for Japan and the United States (in million of dollars) and by the Center for Risk Management Lausanne (CRML) for the euro area (in billion of euro). The SRISK indicator is mostly used to identify systemically impor-

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<sup>26</sup>For further details on these hyper-parameters, see Dieppe, Roye, and Legrand (2016)

tant financial institutions (SIFIs) at micro-level (Banulescu and Dumitrescu 2015; Benoit, Colliard, et al. 2017), but there already exist a growing number of studies using this indicator as a proxy for aggregate systemic risk at macro-level in the financial system (R. Engle, Jondeau, and Rockinger 2015; Colletaz, Levieuge, and Popescu 2018). At the individual level, SRISK corresponds to “the expected capital shortfall of a given financial institution, conditional on a crisis affecting the whole financial system” (Benoit, Colliard, et al. 2017). This measure combines an economic analysis of Acharya, R. Engle, and Richardson (2012) and an econometric model developed by Brownlees and R. Engle (2012). This measure is based exclusively on publicly available information (market and accounting data): (i) the market capitalization of firms, (ii) their financial leverage and (iii) data related to the sensitivity of the equity return to market shocks. Therefore, it accounts not only for the size of the institution and its individual risk, but also for the correlations between the market and the firm’s return. It hence takes into account the two main components of systemic risk, size and interconnectedness (Colletaz, Levieuge, and Popescu 2018). The idea behind the aggregate measure of systemic risk, which is common to use in the literature of systemic risk, is that the total amount of capital that would be needed to bail out the financial system if a financial crisis were to occur is the sum of all the capital needed by each institution. Aggregate SRISK can be thought of as a stress test on the financial system, where the adverse case scenario is defined as a 40% decrease of the global equity market over a 6-month time horizon. This aggregate SRISK is based on four types of financial firms: banking institutions, insurance companies, financial services and real estate firms. According to Deev and Hodula (2016), who evaluate the performance of three systemic risk measures for the euro area (SRISK, Composite Indicator of Systemic Stress, and term-spread) using combination of Markov-switching models and dynamic conditional correlation models, the SRISK indicator seems to identify successfully the accumulation phases that might eventually lead to financial instability. Regarding our balance sheet policies proxy variable, we use the central bank total assets’ growth, following Altunbas, Gambacorta, and Marques-Ibanez (2014), Boeckx, Dossche, and Peersman (2017), Kremer (2016), Burriel and Galesi (2018), Gambetti and Musso (2020). The use of this proxy is criticised by some authors (Elbourne, Ji, and Duijndam 2018; Kanga and Levieuge 2017) who argue that balance sheet policies are generally announced



in advance for a given period and therefore that balance sheet changes are largely anticipated by economic agents. However the overall stance of the various forms of balance sheet measures are mainly manifested by the increase in the size of the balance sheet. This variable appears therefore to be the most relevant regarding the aim of this study, which is to capture the total effect of balance sheet policies.

### 3.2 Identification of balance sheet shocks

Economic research faces new econometric challenges with the identification and the estimation of monetary policy shocks since the development of BSP tools. Assessing the effects of monetary policy on real and financial variables requires the identification of monetary policy shocks. These shocks should be exogenous with respect to the other current and lagged endogenous variables in the model, uncorrelated with other exogenous shocks and representing either unanticipated movements in exogenous variables or news about future movements in exogenous variables (Ramey 2016). Before the global financial crisis, monetary policy was usually examined in the context of one instrument, typically the policy rate. At the effective lower bound, unconventional measures describe almost all the stance of monetary policy. However, no particular observables directly represent these new instruments. Furthermore, the unconventional monetary policy period is relatively short, starting mainly from the aftermath of the crisis. This small number of observations can lead to estimation uncertainty and to a lack of identification (Rossi 2019). Thus, new identification schemes that are suitable at the effective lower bound have been developed following the 2007-08 crisis<sup>27</sup>, but there is still no consensus on the most appropriate method for measuring monetary policy shocks.

In line with Boeckx, Dossche, and Peersman (2017), we use a mixture of zero and sign restrictions on the contemporaneous matrix B in equation (1) to identify exogenous central bank balance sheet shock. This identification strategy is also typically used in the monetary policy literature (Altunbas, Gambacorta, and Marques-Ibanez 2014; Weale and Tomasz Wieladek 2016; Boeckx, Dossche, and Peersman 2017; Burriel and Galesi 2018; Lewis and Roth 2019). Our identifying restrictions are

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<sup>27</sup>Shadow Rates (Wu & Xia 2016), Heteroskedasticity-based Identification (Brunnermeier, Palia, Sastry and Sims 2018), high-Frequency Identification and Event-Study Approaches (Gürkaynak, Sack and Swanson 2005), external instruments (Montiel-Olea et al., 2012)...  
See the Appendix A.1 for more details of identification schemes)

summarized in tables 3 and 4. The balance sheet policies and the conventional monetary policy shocks are respectively annotated "bsp" and "cmp".

Table 3: Sign and zero restrictions values

<b>Variables/Shocks</b>	srisk	bsp	supply	demand	cmp
srisk	+				
total assets		+			0
cpi		+	-	+	+
production index		+	+	+	+
short-term interbank rate		0			-

Notes: ‘+’/ ‘-’ indicates that the impulse response is positive/negative to the shock. For example, the production index responds positively to a balance sheet policy shock.

Table 4: Sign and zero restrictions periods

<b>Variables/Shocks</b>	srisk	bsp	supply	demand	cmp
srisk	0 1				
total assets		0 1			0 1
cpi		1 2	0 1	0 1	0 1
production index		1 2	0 1	0 1	0 1
short-term rate		0 1			0 1

Notes: ‘0 1’/ ‘1 2’ indicates the number of month after the shock during the variable responds positively/negatively to the shock. All the other sign restrictions are imposed upon impact and one month thereafter (‘0 1’) except the sign restrictions of the cpi and the production index for the "bsp" shock.

Our identification scheme is drawn from the results of the economic literature. The first two aggregate shocks are the demand and the supply shocks. These shocks are intended to capture important factors driving fluctuations in the real economy and are included in the model to ensure that the central bank balance sheet shocks are exogenous rather than endogenous responses to macroeconomic conditions. The restrictions used to identify these aggregate shocks are well established in the literature on the basis of standard theoretical models: after an aggregate supply shock, inflation and output move in opposite directions, while they move in the same direction after an aggregate demand shock (Peersman and Straub 2009; Elbourne, Ji, and Duijndam 2018). The third identified shock is a conventional monetary policy (cmp) shock, which leads to a rise in prices, output, and

has zero impact on central bank’s total assets. To identify BSP shocks, we first follow most of the literature on monetary policy by assuming that output and prices respond positively to BSP shocks (Altunbas, Gambacorta, and Marques-Ibanez 2014; Ryuzo and Tatsuyoshi 2017; End and Pattipeilohy 2015). Moreover, output and prices only respond with a lag to monetary disturbances (see, for example, Elbourne, Ji, and Duijndam (2018)). All the other sign restrictions are imposed upon impact and one month thereafter. Third, due to an endogeneity issue, we must add the following constraint: the srisk indicator responds negatively, in the very-short term, to an increase in the size of the central bank’s balance sheet. This restriction is required to disentangle such innovations from the endogenous very short-term response of the balance sheet to financial stress (Altunbas, Gambacorta, and Marques-Ibanez 2014; Boeckx, Dossche, and Peersman 2017).<sup>28</sup> Finally, given that we want to estimate the dynamic effects of shocks to central bank balance sheet that are orthogonal to shifts in the monetary policy rate (conventional monetary policy), the identified shocks have a zero contemporaneous impact on the short term interest rate.

### 3.3 Results

#### 3.3.1 Impulse response analysis

Figures 2, 3 and 4 presents the monthly impulse response functions (IRFs) of the SRISK indicator to a one-standard-deviation balance sheet innovation (BSP shock) and to a one-standard-deviation of the short-term interest rate (CMP shock)<sup>29</sup>. Red dots depict the median, the dark blue-shaded band the associated 95-percent confidence intervals and the light blue-shaded band the associated 68-percent confidence intervals. Aggregated SRISK indicator is in million of dollars for Japan and the United-States (V-Lab) and in billion of euro for the euro area (CRML), which explains the differences in the values on the Y axis for the euro area. We fix our IRFs periods to 60 months.

While being (weakly) imposed by the sign restriction on impact and the first month after the shock, an expansionary balance sheet shock leads to a significant decline of the SRISK indicator. More

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<sup>28</sup>We do the exercise of removing the bsp shock constraint on srisk and imposing a positive shock on srisk. Central bank’s total assets react positively to a rise in financial stress. So, without the constraint of the bsp shock on srisk, our balance sheet shock captures only its reaction to financial stress.

<sup>29</sup>All the endogenous response to all the shocks are presented in the Appendix A.2, A.3, A.4

precisely, the response of the systemic risk is statistically different from zero at the 68 percent confidence intervals during twelve months after the shock for the euro area and the United States, and during five years after the shock for Japan (six months for the euro area and the United States and twenty-four months for Japan at the 90 percent confidence intervals). The effect fades out gradually and returns progressively to the baseline. During our sample period, central banks were often concerned with ensuring the functioning and the stability of the financial system. This result brings evidence that BSP has been successful at reducing financial market failures. Moreover, it would seem that even in the medium term (or even in the long run for Japan), these instruments continue to have a positive effect on financial stability. Our results are robust to the use of an alternative systemic risk measure, the CISS index<sup>30</sup> (see the Appendix A.5 and A.6 for the IRFs with the CISS index for the United-States and the euro area).

Conversely, conventional monetary policy shocks lead in the very short term to an increase of the systemic risk in the euro area, and have no significant effect in the United States and Japan. This is in line with the fact that, before the financial crisis, central banks were not acting on financial stability. The lack of effects in the United States and Japan may also come from the fact that short-term rates were stuck at the effective lower bound.

The dynamics of real GDP and consumer prices reveal that balance sheet policies conducted in the aftermath of the financial crisis were effective in supporting the macroeconomy. Both variables display a significant increase after an expansion in the central bank balance sheet. The response pattern of output turns out to be qualitatively very similar to a conventional monetary policy shock.

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<sup>30</sup>The CISS is computed for the Euro Area and the United States. It includes 15 raw, mainly market-based financial stress measures that are split equally into five categories, namely the financial intermediaries sector, money markets, equity markets, bond markets and foreign exchange markets. For further details, see Holló, D., Kremer, M. and Lo Duca, M., "CISS - A Composite Indicator of Systemic Stress in the Financial System" , Working Paper Series, No 1426, ECB, March 2012.

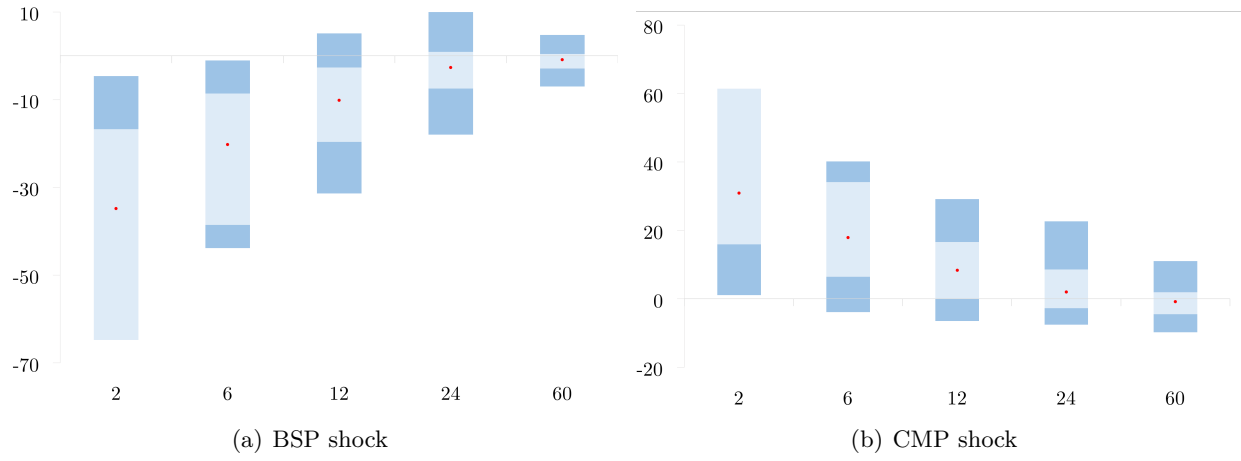


Figure 2: Impact of monetary policy shocks on the SRISK in the euro area

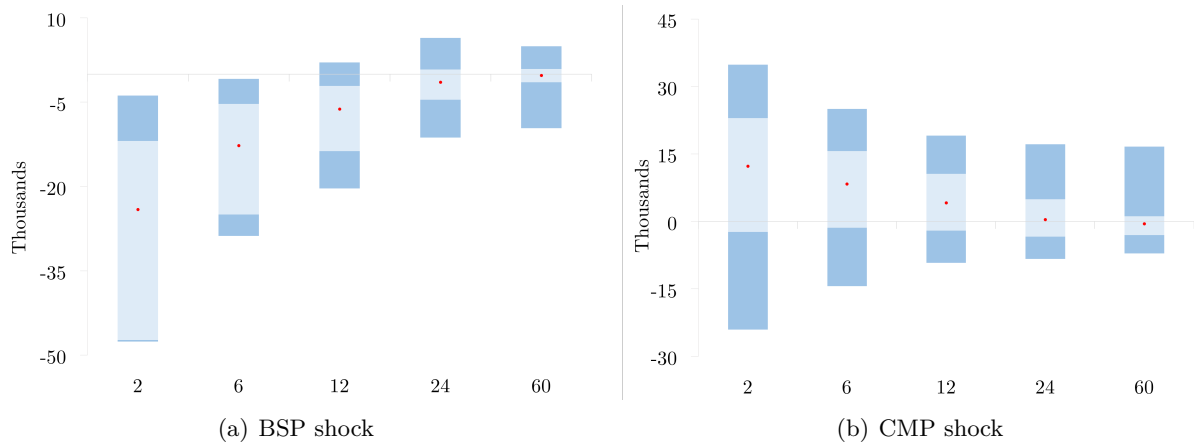


Figure 3: Impact of monetary policy shocks on the SRISK in the United States

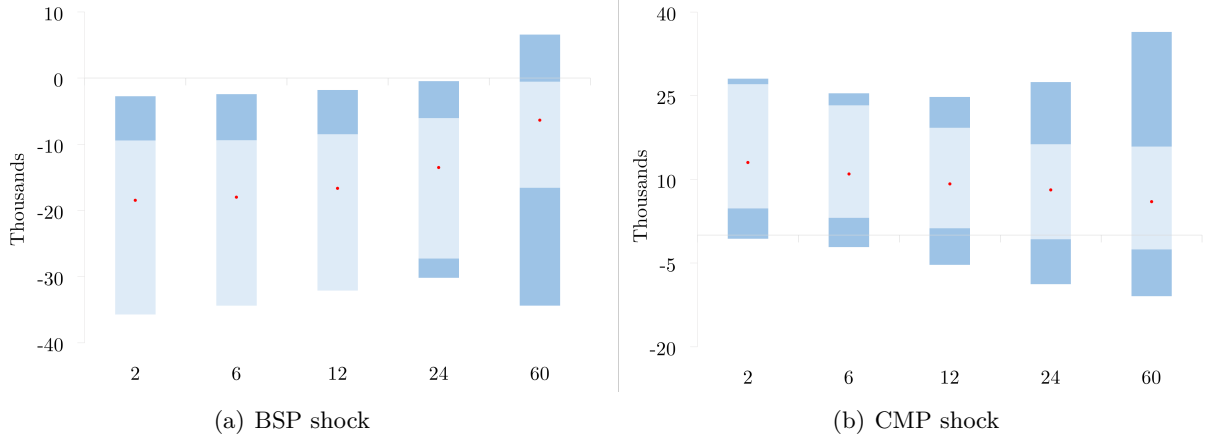


Figure 4: Impact of monetary policy shocks on the SRISK in Japan

Note: Figures 2, 3 & 4 show the median impulse responses of the SRISK in response to a BSP shock (on the left) and to a CMP shock (on the right). Red dots depict the median, the light blue-shaded area the associated 68-percent confidence interval from the BVAR and the dark blue shaded area the 95-percent confidence interval. The horizontal axis indicates the number of monthly time periods since the shock. All the endogenous variables have 6 lags.

### 3.3.2 What about the effects of balance sheet shocks on asset price misalignments?

While we have so far focused on the effect of central bank balance sheet policies on the SRISK measure, in order to draw conclusions about the link between balance sheet policies and financial stability, the latter also includes risk related to asset price bubbles, i.e. valuations that deviate from their fundamental value. Bursting asset price bubbles can have detrimental effects on the financial system and give rise to systemic financial crises (example of the one preceding the global financial crisis). Therefore, it is worth reestimating our BVAR model by replacing the SRISK indicator with an asset price bubble indicator. Indeed, if balance sheet policies reduce the systemic risk contribution of financial firms (SRISK indicator), they can negatively affect financial stability through the formation of asset price bubbles. In particular, one of the intended effects of asset purchase programs, artificially lowering risk premia, introduces the risk of inflating asset pricing bubbles. Furthermore, the search for yield caused by asset purchases reduce long term interest rates, leading potentially to an increase in the price of risky assets to a level that lies above their fundamental value (Hudepohl, Lamoen, and Vette 2019). Rising asset prices are one of

the transmission channels of monetary policy, but the key question is whether these rising prices are disconnected from fundamentals and reflect the emergence of a bubble. To build our bubble indicator, we follow the methodology of Blot, Hubert, and Labondance (2020a). First, we calculate the bubble component of stock prices for the United-States, the euro area and Japan with three alternative methods: (i) the "structural", (ii) the "data-driven", and (iii) the "statistical" approaches. The first consists of capturing the bubble component as the deviation from the fundamental value derived from the estimation of a simplified discounted cash-flow model. Under the second approach, we estimate a model where the stock price index is explained by macroeconomic and financial variables. The asset price bubble indicator corresponds to the residuals of the equation. The third method consists simply of identifying deviations from a statistical trend. Then, we summarize the information in a composite indicator by using a principal-component analysis (PCA). The first principal component corresponds to the common denominator of the three approaches (see figures 35, 36, 37 of the Appendix A.7). Regarding the impulse responses of the asset price bubble indicator to conventional monetary policy shock, we find no significant results. Otherwise, our findings suggest that central bank balance sheet shocks have no significant effects on asset price bubbles, over all horizons and for the three areas (figures 5, 6, 7). Therefore, during our study period, the positive effects of balance sheet policies on the aggregate systemic risk do not seem to be counterbalanced by the emergence of asset price bubbles. In other words, our results reject the idea that asset purchase programmes lead to disproportionate increases in stock prices. Our results are in line with Blot, Hubert, and Labondance (2020a) who focus on the bubble component of asset prices and find that the risk that quantitative easing would inflate asset price bubbles does not materialize in the data over the period January 1999 to June 2016 in the euro area. Their results even indicate that positive balance sheet shocks tend to lessen the bubble component of stock prices. Hudepohl, Lamoen, and Vette (2019) who use the GSADF-test, a recent advances in bubble detection techniques, find that the announcement and the start of asset purchases programmes in the euro area led to an exuberant increase in the stock prices in several countries, even after controlling for improving fundamentals. This issue is not consensual within the monetary policy literature and central banks need to know if monetary policy have negative side-effects on financial

stability through its effects on asset prices.

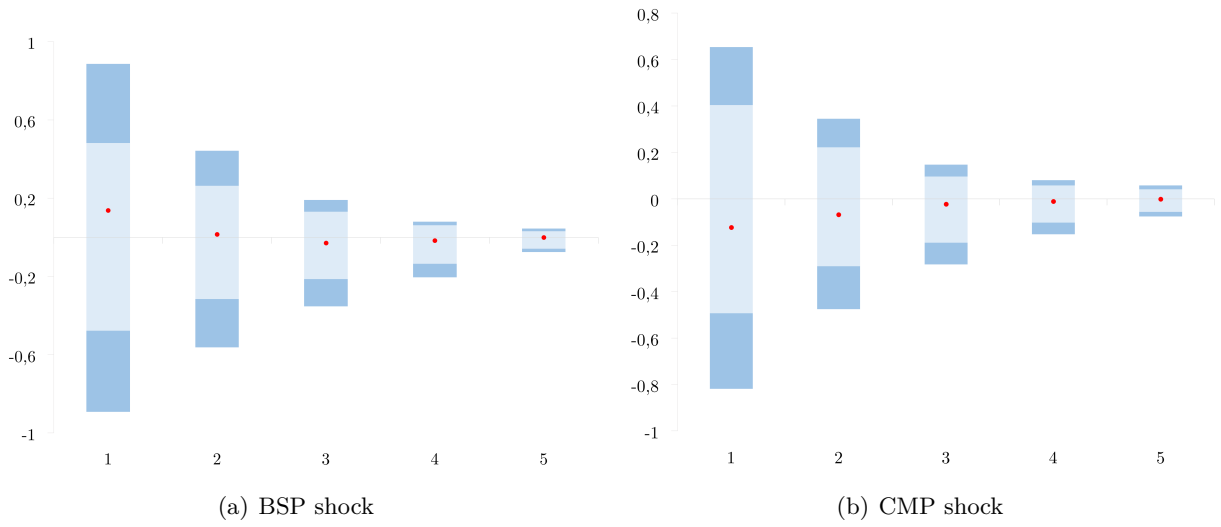


Figure 5: Impact of monetary policy shocks on the asset price bubble indicator in the euro area

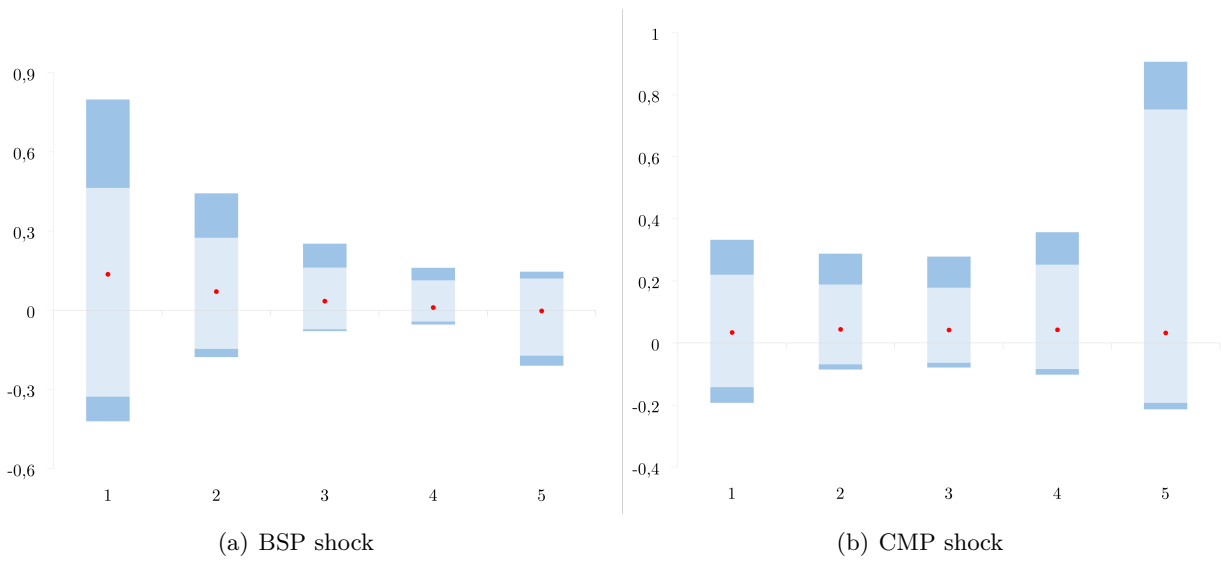


Figure 6: Impact of monetary policy shocks on the asset price bubble indicator in the United States



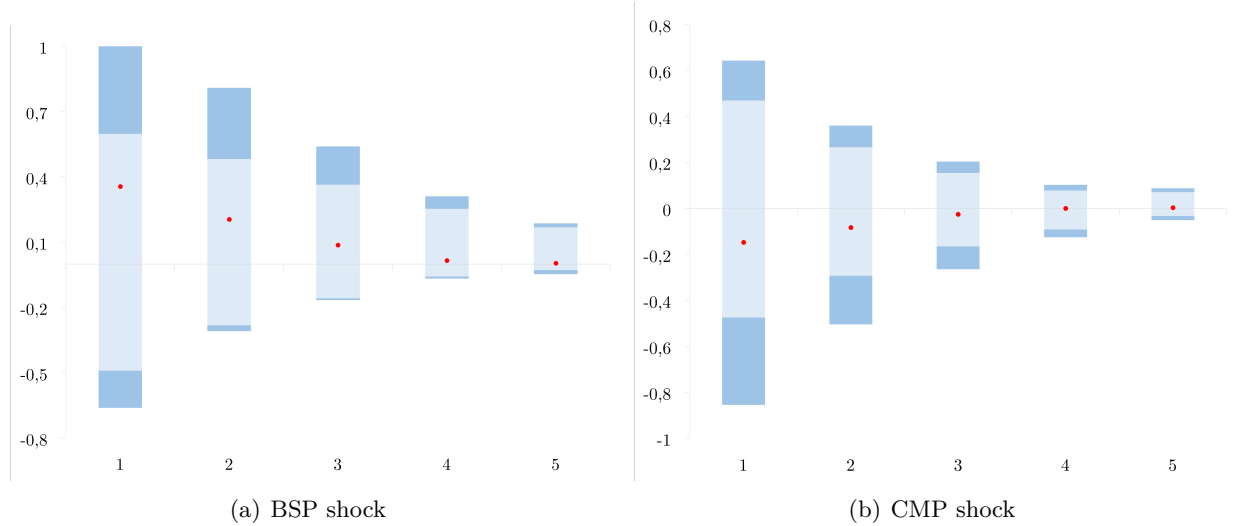


Figure 7: Impact of monetary policy shocks on the asset price bubble indicator in Japan

Note: Figures 5, 6 & 7 show the median impulse responses of the measure of equity market overvaluation in response to a BSP shock (on the left) and to a CMP shock (on the right). Red dots depict the median, the light blue-shaded area the associated 68-percent confidence interval from the BVAR and the dark blue shaded area the 95-percent confidence interval. The horizontal axis indicates the number of monthly time periods since the shock.

### 3.3.3 Historical decomposition analysis

Historical decomposition simulates the dynamics of the system over the sample period and for each of the observed series, indicating the contribution to the historical value observed at each date from each structural shocks (calculated as the median of the posterior distribution).

Figures 8, 9 and 10 present the historical decomposition of the SRISK indicator over the sample period, showing the contribution of a particular shock to the SRISK in the euro area, the United States and Japan. We focus on the contribution of BSP shocks and CMP shocks. For the three areas, CMP shocks make a much smaller contribution than BSP shocks to the SRISK fluctuations. This finding is consistent with the view that since the global financial crisis and also the use of BSP tools, central banks respond more or less implicitly to financial stability objectives. In the U.S., the SRISK increases from 2011 to 2012 but BSP shocks contribute negatively to the evolution of this variable. During the same period, two asset purchase programmes were set up, LSAP2 (12.11.2010) and MEP (03.10.2011). Moreover, the sharp decline in the SRISK indicator over the period from

2013 to the end of 2014 was almost entirely driven by innovations to BSP, which may be related to the launch of the LSAP3 treasuries (03.01.2013). However, BSP shocks contribute to the rise of the SRISK since the end of 2015. It coincides with the normalisation of the Fed's monetary policy which began at the end of 2014. In Japan, BSP shocks are the main contributors to the increase in the SRISK over the 2010 - 2013 period but play an important role in the decrease in the SRISK between 2013 and 2016. The direction of the relationship appears to coincide with the degree of monetary policy accommodation. After a number of years of QE policies including subsequent rounds of asset purchases as part of its "Comprehensive Monetary Easing" (CME) policies in 2010-2013, the BOJ, in April 2013, took monetary easing one step further by introducing Quantitative and Qualitative Monetary Easing (QQE). QQE aimed at doubling the monetary base and changing the composition of asset purchases, with greater emphasis on longer-dated government securities and expanding purchases of risk assets such as commercial paper, corporate bonds, exchange-traded funds and Japanese REITs. With the introduction of this program, the degree of accommodation of Japanese monetary policy has greatly increased. Figure 10 indicates that Japan's monetary policy from 2013 onwards has been sufficiently accommodative to reduce systemic risk. In the euro area, the decomposition suggests that decreases of the SRISK over the period 2009 - 2010 and in 2015 has been mainly attributable to BSP shocks, but BSP contributes also to increases of the SRISK between 2012 and 2013 and between 2016 and 2017. Between 2009 and 2010, the ECB launched the Covered Bond Purchase Programme (CBPP1) in July 2009 and the Securities Market Programme (SMP) in May 2010. The aim of the first programme has been to "support a specific financial market segment that is important for the funding of banks and that had been particularly affected by the financial crisis" (ECB press release, 30 June 2010). The SMP was intended to ensure depth and liquidity in malfunctioning segments of the debt securities markets. In 2015, the ECB launched its Public Sector Purchase Programme (PSPP) in order to maintain bond and repo market liquidity by supporting market making for the securities. Henceforth, these three programmes, which were intended to enhance financial stability, did contribute to the decline of the SRISK. Regarding the periods during which BSP shocks contributed to the rise in the SRISK, the ECB launched the Long Term Financial Operations II in February 2012, the Targeted Long Term Financial Operations II

and the Corporate Sector Purchase Programme (CSPP) in June 2016. While it may seem counter-intuitive that these programs have contributed to the increase in systemic risk (effect contrary to its intention), such results could indicate that the markets were expecting a stronger action from the central bank.

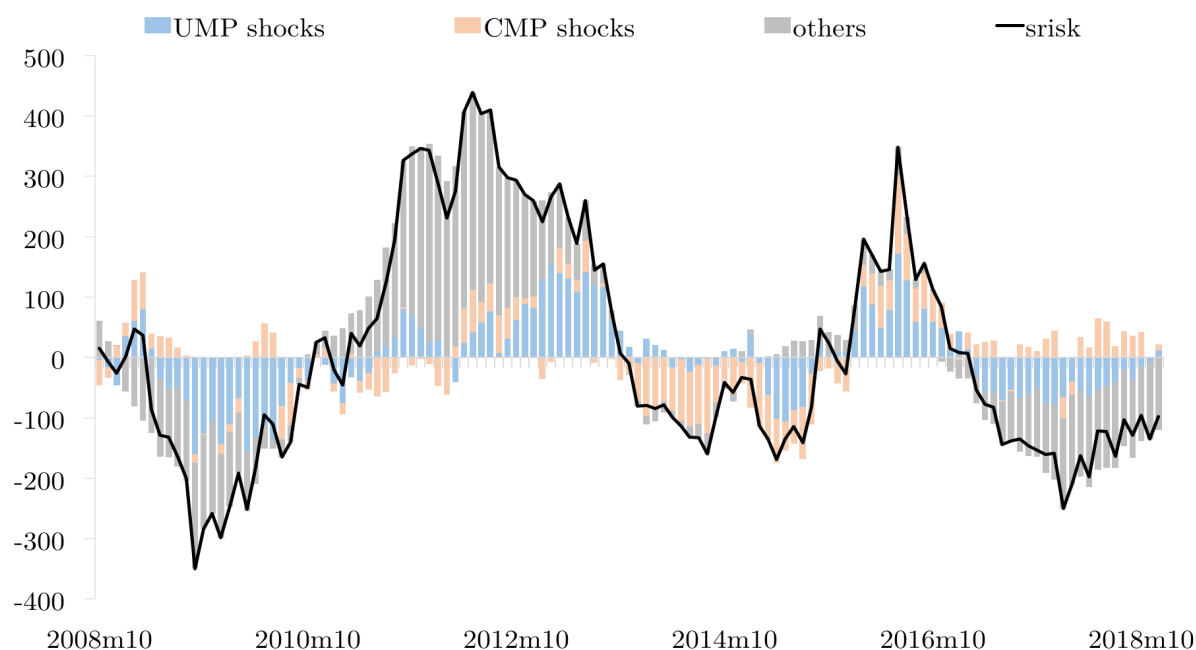


Figure 8: Euro area - Contribution of BSP and CMP shocks in the SRISK fluctuations

Note: Figures 8, 9 & 10 show the contribution of BSP (blue), CMP (pink) and others (supply, demand, in grey) shocks to explaining the deviation of our key variables, the srisk, from their deterministic component (solid line in dark).

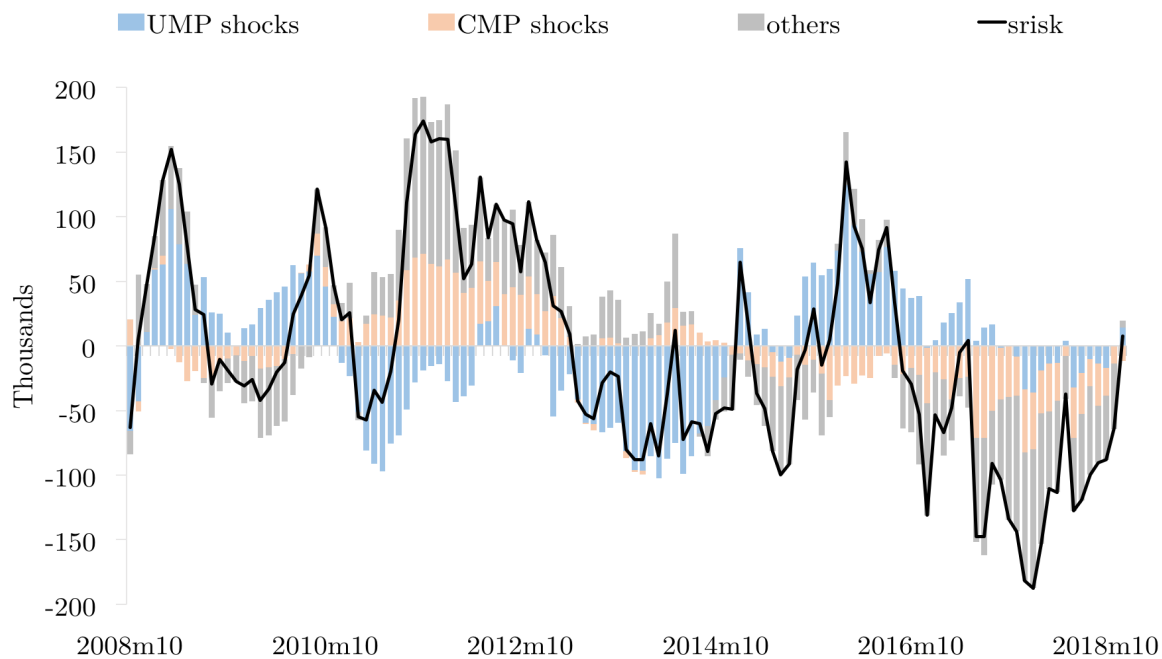


Figure 9: U.S. - Contribution of BSP and CMP shocks in the SRISK fluctuations

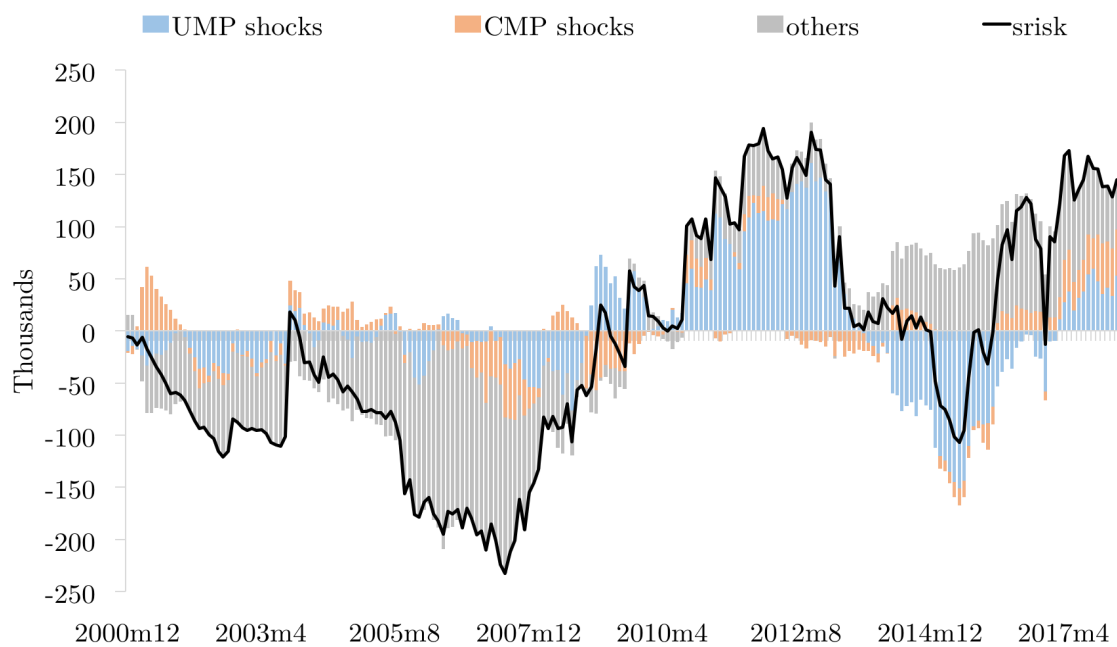


Figure 10: Japan - Contribution of BSP and CMP shocks in the SRISK fluctuations

## 4 Balance sheet policies and systemic risk at a disaggregated level

The previous section highlighted the total impact of balance sheet policies on the overall systemic risk in our three research areas. We have shown that balance sheet policies tend to reduce the aggregate systemic risk in the euro area, the United States and Japan in the short and medium term. However, this macroeconomic perspective does not allow us to perceive a possible heterogeneous effect of these measures within the financial sectors. In this section, we revisit the relationship between central bank balance sheet policies and systemic risk by adopting a firm-level approach. The objectives are (i) to verify if we find similar results at a disaggregated level and also (ii) to study the possible heterogeneous effects of balance sheet shocks on financial firms' SRISK. This second aim is linked to the literature relative to monetary policy transmission and financial institutions' heterogeneity. The importance of financial institutions' characteristics in the transmission of monetary policy to the real economy, especially through the lending channel has been demonstrated. Higher bank capital is associated with greater lending, and the mechanism involved in this channel is the lower funding costs associated with better capitalised banks (Gambacorta and Shin 2018; Acharya and Ryan 2016). The role of asset, funding, capital, income structure, is also important in the transmission of monetary policy to bank's systemic risk. An expansionary monetary policy shock reduces systemic risk more for banks with higher asset risk in the two areas. This indicates the presence of a recapitalization effect, i.e. the accommodative monetary policy shock increases security prices and de facto causes a positive revaluation of the banks' securities portfolios. Moreover, improved collateral values may furthermore decrease the probability of default within the banks' loan portfolios (Lamers et al. 2019). Similar results have previously been demonstrated by Delis and Kouretas (2011) and Ricci (2015) who respectively find that the increase bank risk-taking due to low interest rates is more pronounced for euro area banks with low level of risk asset and that stock prices of European banks with weaker balance sheets and operating with high-risk were more sensitive to monetary policy interventions.

## 4.1 Empirical approach

### 4.1.1 Data

We use a Bayesian Panel VAR model<sup>31</sup> for each of our study areas, consisting of monthly data for different financial firms, overall the sample period 2008–2018 for the EA and the U.S. and 2000–2018 for Japan. We use the same sign and zero restrictions values and periods as in section I (see tables 3 and 4). Our three samples contain the financial institutions whose SRISK is calculated by the V-lab institute, including depositories, broker-Dealers, insurance, non depository institutions and real estate. We exclude financial firms with significant missing data during our study period. The samples for the Eurozone and the United States contain 100 firms and the sample for Japan contains 40 firms. The panel VAR allows us to embed banks' cross-sectional heterogeneity. Moreover, as the objective of our empirical exercise is to infer average dynamic responses to shocks of interest, the Bayesian PVAR pooled estimator is used.

The benchmark panel VAR model for unit  $i$  (with  $i = 1, 2, \dots, N$ ) has the following representation:

$$Y_{i,t} = \sum_{j=1}^N \sum_{k=1}^p A_{ij,t}^k Y_{j,t-k} + C_{i,t} x_t + \beta \epsilon_{i,t} \quad (10)$$

$Y_{it}$  denotes a  $n \times 1$  vector comprising the  $n$  endogenous variables of unit  $i$  at time  $t$ , while  $Y_{ij,t}$  is the  $j^{th}$  endogenous variables of unit  $i$ .  $A_{ij,t}^k$  is a  $n \times n$  matrix of coefficients providing the response of unit  $i$  to the  $k^{th}$  lag of unit  $j$  at period  $t$ . For matrix  $A_{ij,t}^k$ , the coefficient  $a_{ij,lm,t}^k$  gives the response of variable  $l$  of unit  $i$  to the  $k^{th}$  lag of variable  $m$  of unit  $j$ .  $x_t$  is the  $m \times 1$  vector of exogenous variables, and  $C_{i,t}$  is the  $n \times m$  matrix relating the endogenous variables to these exogenous variables. For  $C_{i,t}$ , the coefficient  $c_{ij,l,t}^k$  gives the response of endogenous variable  $j$  of unit  $i$  to the  $l^{th}$  exogenous variable. Finally,  $\epsilon_{i,t}$  denotes a  $n \times 1$  vector of residuals for the variables of unit  $i$ , with the following properties:

$$\epsilon_{i,t} \sim N(0, \epsilon_{ii,t}) \quad (11)$$

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<sup>31</sup>The model is implemented and described in the BEAR toolbox, Dieppe, Roye, and Legrand (2016).

With:

$$\sum_{ii,t} = E(\epsilon_{i,t}\epsilon'_{i,t}) = E \begin{pmatrix} \epsilon_{i,1,t} \\ \epsilon_{i,2,t} \\ \vdots \\ \epsilon_{i,n,t} \end{pmatrix} \begin{pmatrix} \epsilon'_{i,1,t} & \epsilon'_{i,2,t} & \dots & \epsilon'_{i,n,t} \end{pmatrix} = \underbrace{\begin{pmatrix} \sigma_{ii,11,t} & \sigma_{ii,12,t} & \dots & \sigma_{ii,1n,t} \\ \sigma_{ii,21,t} & \sigma_{ii,22,t} & \dots & \sigma_{ii,2n,t} \\ \dots & \dots & \ddots & \dots \\ \sigma_{ii,n1,t} & \sigma_{ii,n2,t} & \dots & \sigma_{ii,nn,t} \end{pmatrix}}_{n \times n} \quad (12)$$

$\epsilon_{i,t}$  is assumed to be non-autocorrelated, so that  $E(\epsilon_{i,t}\epsilon'_{i,t}) = \sum_{ii,t}$ , while  $E(\epsilon_{i,t}\epsilon'_{i,s}) = 0$  when  $t \neq s$ . In this general setting the variance-covariance matrix for the VAR residuals is allowed to be period-specific, which implies a general form of heteroskedasticity.

Our dataset contains the same variables as our precedent BVAR model in section I (consumer price index, industrial production index, central bank total assets, short-term interest rate). We add financial institutions' systemic risk and control variables for financial institutions, (i) financial leverage<sup>32</sup>, (ii) LRMES<sup>33</sup> and (iii) market capitalisation<sup>34</sup>. This allows us to control for the size, the risk and the leverage effects. Data specific to financial firms (SRISK, LRMES, leverage) comes from V-Lab website and the market capitalisation from Bloomberg. LRMES (Long-Run Marginal Expected Shortfall) is defined as the expected fractional loss of the firm equity when the MSCI World Index declines significantly in a six-month period. It measures how much equity would be needed to cover losses in the event of a systemic crisis. Regarding the leverage measure used by the V-Lab institute, it is the financial leverage of a company which is 1 plus its book value of liabilities divided by its market value of equity.

As a first step, we obtain the impulse responses functions of the financial institutions' SRISK including all financial institutions in our sample for each zone. The results are fully consistent with those obtained earlier at aggregate level: central bank balance sheet policies seems to lower the financial institutions' systemic risk in the short and medium term.

In a second stage, for each area, as in Faia and Karau (2019), we split the sample of financial firms into two groups (see table 15 in Appendix A.8 and tables 16 and 17 in Appendix A.9 for

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<sup>32</sup>The ratio of the value of the assets of the firm to the value of its equity.

<sup>33</sup>The sensitivity of the return on equity of the firm to whole-market shocks.

<sup>34</sup>The value of the equity of the firm.

descriptive statistics), according to their leverage, in order to study the role of potential fragilities of each individual institutions in the transmission of central bank balance sheet shocks to individual systemic risk measures. We select the 12 firms with the lowest leverage (Model 1 in blue) and the 12 firms with the highest leverage (Model 2 in red).

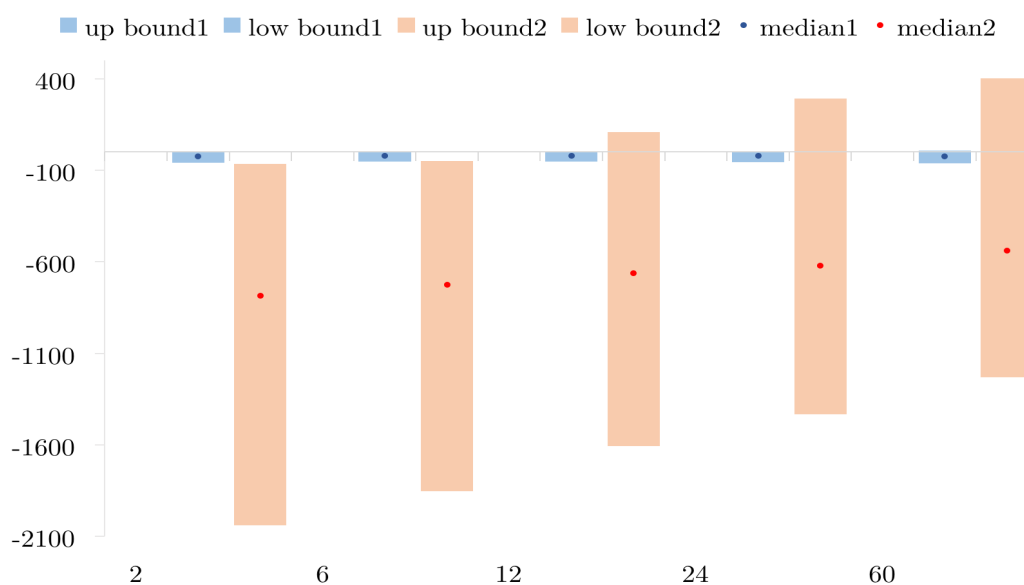
#### 4.1.2 Results

Figures 11, 12 and 13 show the IRFs of the SRISK of the two groups of financial firms to a balance sheet shock (in blue the 95-percent confidence intervals of the group of financials with the lowest level of leverage ; in orange those of the group with the highest level of leverage). Impulse responses from the institutions with the lowest leverage are not significant at any horizon for the euro area and the United States. They are significant only for Japan up to the 12th month but the effects are very small. These results seem consistent given that financial institutions with low leverage are not likely to pose a financial stability problem. Thus, central banks have little leeway to reduce their vulnerability. Regarding the other group, the balance sheet shocks substantially affect their SRISK indicator, i.e. balance sheet policies reduce their expected capital shortfall. Impulse responses are significant up to the 6th month for the United States, 12th month for the euro area and up to the 24th month for Japan. This result could first be explained by the fact that the most indebted institutions are also the most vulnerable ones as during downturns, leverage amplifying the losses incurred by investors. As these financial firms take the most risk in terms of purchasing financial assets, they will benefit more from the raise of the value of legacy assets generated by central bank asset purchase programmes with the strengthening of their balance sheet. Also, balance sheet policies will be geared more towards the riskiest banks. For example, when central banks buy back risky securities from banks' balance sheets, these actions will further reduce the systemic risk of the riskiest financial institutions. This may also explain the longer duration of the effects of balance sheet policies in the case of Japan ; the BoJ buys ETFs (the riskiest assets) since 2010. An other effect of balance sheet policies, is to reduce delinquency and default rates and to raise profits, by promoting recovery in the real economy. This effect is stronger for banks with the highest leverage as they are the ones who grant the most loans. Overall, our results suggest



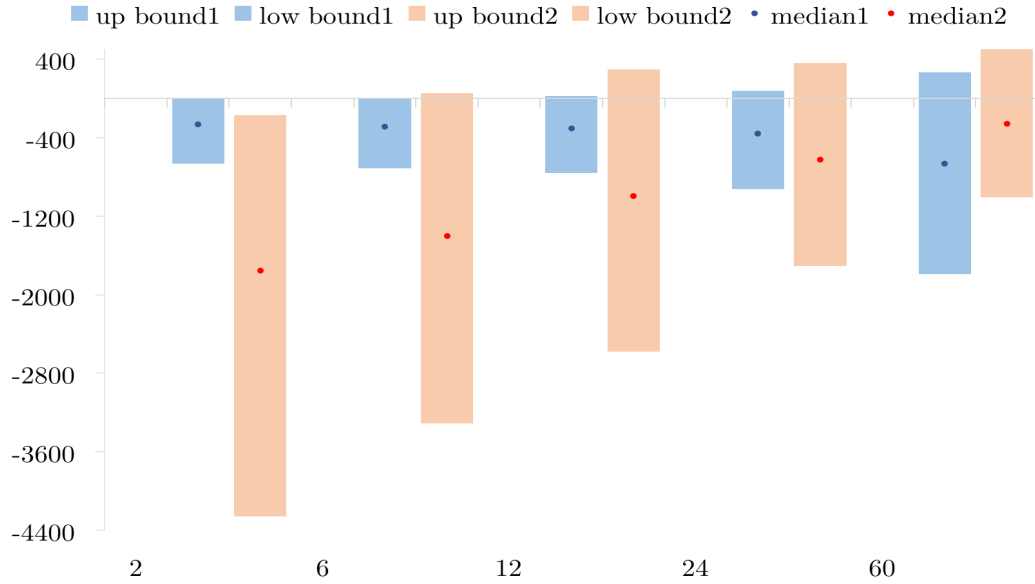
that the effects of balance sheet policies on stock market and on the economic activity, which are reflected in the reduction of the SRISK, more than offset the negative impact of low interest rate on the risk-taking behavior. Our findings are close to those of Ricci (2015) or Lamers et al. (2019), i.e. central bank balance sheet shocks reduces systemic risk more for the financial institutions with the highest leverage.

Figure 11: Euro area - Impulse response functions of the SRISK to BSP shock



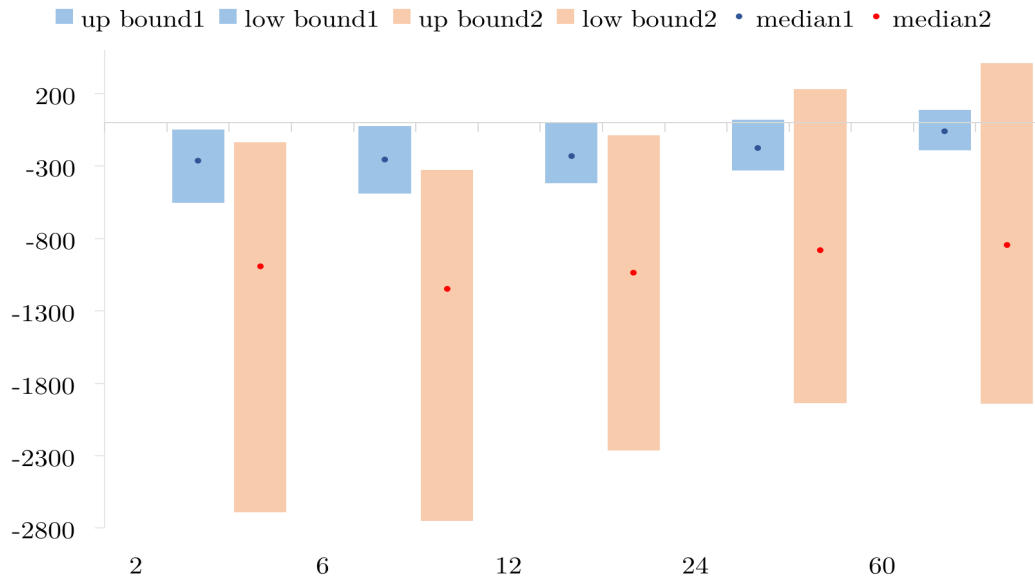
Notes: This figure shows, the median impulse responses (dots) of the srisk of the 12 financial firms in response to a balance sheet policy unexpected shock, together with 95% confidence bands. The group in red corresponds to the 12 firms with the highest level of financial leverage. The group in blue in blue corresponds to the 12 firms with the lowest level of financial leverage.

Figure 12: U.S. - Impulse response functions of the SRISK to BSP shock



Notes: This figure shows, the median impulse responses (dots) of the srisk of the 12 financial firms in response to a balance sheet policy unexpected shock, together with 95% confidence bands. The group in red corresponds to the 12 firms with the highest level of financial leverage. The group in blue in blue corresponds to the 12 firms with the lowest level of financial leverage.

Figure 13: Japan - Impulse response functions of the SRISK to BSP shock



Notes: This figure shows, the median impulse responses (dots) of the srisk of the 12 financial firms in response to a balance sheet policy unexpected shock, together with 95% confidence bands. The group in red corresponds to the 12 firms with the highest level of financial leverage. The group in blue in blue corresponds to the 12 firms with the lowest level of financial leverage.

## 5 Conclusion

In this paper, we analyse the effects of balance sheet policies on systemic risk in the euro area, the United States and Japan, using a monthly structural BVAR model in the first part of our empirical study and a panel VAR model in the second part, using sign and zero restrictions as our identification strategy of balance sheet shocks. Our empirical analysis shows that asset purchases programs and lending programs of central banks have significantly decreased the aggregate systemic risk in the short and medium term. In the long-term, these shocks do not appear to pose a threat to financial stability as they do not lead to significant effects on systemic risk indicators. We also find that BSP has a heterogeneous effect on financial institutions, the effects being more effective for those with the highest leverage. Overall, our findings contribute to the recent literature on the link between BSP and financial stability by showing that central banks' balance sheet policies lower the systemic risks several months after their implementation. These results are robust to the use of two different approaches: a macroeconomic approach and a firm-level approach.

# CHAPTER 2

## Multidimensional monetary policy & financial stability<sup>35</sup>

*« We need to further our understanding of the transmission channels of our different instruments, and to evaluate their relative side effects, both intended and unintended, as they work their way through the economy. » (Christine Lagarde, President of the ECB, at the “ECB and Its Watchers XXI” conference, September 2020)*

### 1 Introduction

The use of unconventional monetary policy (UMP) instruments, implemented after the global financial crisis of 2007-2008, has proved to be effective to reach macroeconomic objectives and alleviate financial frictions. These "new"<sup>36</sup> monetary policy tools, including asset purchase programs, term funding facilities and forward guidance, are likely to remain as part of the standard operational monetary policy framework. Therefore, while most papers initially focused on analysing the effectiveness of the UMP instruments on economic and financial variables (Gambacorta, Hofmann, and Peersman 2012; Boeckx, Dossche, and Peersman 2017; Weale and Tomasz Wieladek 2016; Gambetti and Musso 2020), the debate has now turned more about the unintended side effects of UMP tools, especially quantitative easing. Among them, excessive risk-taking and asset overvaluation are

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<sup>35</sup>This Chapter is co-authored by Stéphane Déès.

<sup>36</sup>As mentioned in the general introduction, these instruments are not new in nature, but in their modalities.

regularly mentioned as key issues to be monitored. First, a protracted period of low interest rates and abundant liquidity may over time induce excessive risk-taking by financial intermediaries. This behavior can be reinforced by the increase in moral hazard due to the fact that financial investors systematically expect the central bank to intervene whenever asset valuations collapse.

Second, balance sheet policies, especially large-scale asset purchases, may fuel asset price bubbles. Although the increase in asset prices since the implementation of quantitative easing has been mostly the result of cheaper borrowing costs, the side effects of this instrument may foster an environment for further bubbles to develop. With the portfolio reallocation channel, investors may not fully appreciate the magnitude of the risk being added to their portfolios as fundamentals may not be improving at the rate at which expansionary monetary policies are affecting the price and yield of securities purchased under their asset purchase programs. Furthermore, the continued search for yield may lead investors to act independently of fundamentals. Overall, these issues may call for the need of coupling quantitative easing policies with adequate regulatory response to avoid asset price booms and increased risk-taking by financial institutions.

In this paper, we develop a framework to assess the potential side effects of UMP tools on financial stability in the U.S. and in the euro area. We focus our analysis on two financial instability indicators, the SRISK and a bubble indicator of stock prices<sup>37</sup>, both reflecting the main risks associated with UMP. Moreover, we address the question if the form of financial instability differ across monetary policy instruments, and if the nature of the assets purchased by central banks influences the impact of quantitative easing on financial stability. Addressing such issues requires a clear identification of monetary policy shocks. A common method in the literature is the high frequency identification approach. It consists of taking up as monetary policy shocks the market responses to monetary policy announcements, that is, the monetary policy surprises in financial markets or the revised expectations of market participants embedded in asset valuations. This method supposes that the monetary policy announcement is the only event impacting asset prices

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<sup>37</sup>The same indicators as those used in Chapter 1

in a tight enough window around the news release (i.e. the content of the news release, in that window, is exogenous to asset prices). Therefore, the high-frequency movements in asset prices provide instruments that can well identify monetary policy shocks. This approach is based on the influential analyses of Cook and Hahn (1989) and K. N. Kuttner (2001). The latter has identified a conventional monetary policy surprise as the change in the current Fed funds futures rate following monetary policy announcement. These studies have developed and have documented more than one dimension of intraday yield changes around central bank’s communications. Gürkaynak, B. Sack, and E. Swanson (2005) show that using intraday data of futures purifies the measurement of the monetary policy surprises by excluding the possibility of contamination by other shocks. They claim that the monetary policy surprises can be characterized by two factors: the “target” factor, which mainly affects the current short-term rates, and the “path” factor, which affects the expected path of future short rates. With the introduction of unconventional monetary policy, Swanson (2021) further claims that there is an additional factor representing the effect of the quantitative easing (QE) policy, which he calls the “QE” factor. For the euro area, Altavilla et al. (2019) construct the Euro Area Monetary Policy Event-Study Database (EA-MPD) which is a compendium of price changes for a wide range of assets like Overnight Indexed Swaps (OIS), exchange rates, stock market indices and sovereign bond yields. They find evidence of a target, timing, forward guidance, and quantitative easing components in monetary policy event window. A recent paper by Martínez-Hernández (2020) proposes a novel high-frequency identification scheme that considers five dimensions of the ECB monetary policy, including target, information, forward guidance, LTRO<sup>38</sup> and quantitative easing surprises. The main novelty of their contribution is to add some identification assumptions to separate the two central bank’s balance sheet factors (LTRO and QE).

The main contribution of our paper to the existing literature is to propose a new decomposition of monetary policy surprises by disentangling QE programs related to public asset purchases ("Public QE") from those implying more risky assets ("Private QE"). This is motivated by emerging questions regarding QE policies which concern the implications of asset purchase programs

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<sup>38</sup>Long Term Refinancing Operations

being extended to private assets that are in nature more risky than public ones. The European Central Bank bought assets with private default risk, such as Asset-Backed-Securities<sup>39</sup> (ABS), covered bonds<sup>40</sup> and Investment Grade corporate bonds<sup>41</sup>. In the U.S., the Federal Reserve is only allowed to purchase securities that are guaranteed by the federal government, i.e. the debt of the government-sponsored entities Fannie Mae and Freddie Mac and the Mortgage-Backed- Securities<sup>42</sup> (MBS) they guarantee. These two categories of assets have greater credit or liquidity risk than Treasury securities. To account for such riskier assets purchases, we add to the Gürkaynak, B. Sack, and E. Swanson (2005) and the Altavilla et al. (2019) datasets the corporate bond spread, which results in the relevant finding of two QE factors instead of one: a public QE factor and a private QE factor. These two factors being not correlated and each responding to specific monetary policy announcements, they may affect financial stability and market valuations differently.

We find some differences in the effect of public QE and private QE on our two financial instability indicators. As expected, private asset purchase programs contribute more to financial system vulnerabilities than public ones. However, in the longer run, the effects of the two types of QE become insignificant, meaning that regardless of the nature and risk of the securities purchased, these measures do not seem to have side effects on financial stability. Moreover, confirming previous findings, when considering the two other factors (target and forward guidance), expansionary surprises also lead to a temporary rise of systemic risk-taking and contribute to asset price bubbles. Overall, our paper therefore confirms the presence of financial stability side effects due to the use of UMP tools by central banks, but these effects are temporary and do not represent a durable threat to financial stability.

The remainder of the paper proceeds as follows. Section 2 reviews the related literature. Sec-

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<sup>39</sup>Financial securities backed by income-generating assets such as credit card receivables, home equity loans, student loans, and auto loans.

<sup>40</sup>Debt instruments secured by a cover pool of mortgage loans or public-sector debt to which investors have a preferential claim in the event of default.

<sup>41</sup>Eligibility criteria for corporate bonds are described in the Decision ECB/2016/16 of 1 June 2016.

<sup>42</sup>Debt obligations that represent claims to the cash flows from pools of mortgage loans, most commonly on residential property.

tion 3 explains our identification strategy and the data used. In Section 4, we give details about our empirical framework based on estimating impulse responses by Smooth Local Projections and analyze the results from a policy viewpoint. Finally, Section 5 concludes.

## 2 Related literature

The large research thematic on the effects of UMP on financial stability can be divided into several strands: (1) the systemic-risk taking channel of UMP, (2) the impact of UMP on asset valuations and (3) more general assessments of UMP effects on financial stability.

First, there is a large literature on the risk-taking channel at a micro-level, as massive liquidity injections aim at flattening yield curves and reducing risk premia. Such implications could encourage financial institutions to take on more risk, reduce their monitoring, and adjust their leverage ratio (Lambert and Ueda 2014; Kandrac and Schlusche 2017; M. D. Delis, Hasan, and Mylonidis 2017). However, the evidence of a risk-taking channel at a micro-level is not sufficient to indicate a threat to financial stability. A close and scarcer literature is developing about the systemic version of the risk-taking channel. Benoit, Colliard, et al. (2017) define systemic risk-taking as the fact that “financial institutions choose to be exposed to similar risks and take large risk exposures, thus reinforcing amplification mechanisms, exposing themselves to default and their counterparts to contagion”. Most papers find that UMP leads to an increase in systemic risk. Among them, Deev and Hodula (2016) demonstrate the risk for financial stability of maintaining central banks’ balance sheet at their current levels. This paper, focusing on the banking sector, suggests that UMP leads to undesired outcomes and aggravates the aggregate SRISK indicator in euro area countries. Faia and Karau (2019) also use the SRISK and other systemic risk indicators (the long-run MES, CoVaR) to assess the systemic risk effects of monetary policy on banks in a sample of 11 countries, covering both conventional monetary policy and UMP periods. They obtain robust evidence of a systemic risk-taking channel across different methodological approaches, using as UMP instruments, shadow rates as well as the size of central banks’ balance sheets. Kabundi and De Simone (2020) also argue that a UMP loosening seems to increase the common component of the contagion



form of systemic risk. This quantitative effect is slightly more important for conventional monetary policy shocks than for UMP shocks. Another paper (Jin and Nadal De Simone 2020), focusing on the effects of monetary policy on systemic risk measures applied to the investment fund industry, confirms that conventional and, to a lesser extent, unconventional monetary policy shocks lead to higher systemic-risk taking in the form of contagion and increased vulnerability.

In contrast, some studies demonstrate a stabilising effect of UMP. For example, Kapinos (2018) finds that expansionary monetary news shocks resulted in large reductions of several systemic risk measures in the U.S. Close findings are put forward by Verhelst (2017) for the euro area. This author obtain evidence that Outright Monetary Transactions (OMT) reduce MES while 3-year long term refinancing operations (LTROs) and fixed-rate full allotment (FRFA) have ambiguous effects in the euro area. We can also mention here a close literature relative to the supply of safe assets to enhance financial stability (surveyed by Golec and Perotti (2017)). For example, Greenwood, Hanson, and Stein (2018) and Woodford (2016) argue that QE is arguably less risky than other expansionary policies because it flattens the yield curve and thus reduces the incentive for maturity transformation.

There is also an abundant literature on the high-frequency effects of UMP on asset prices <sup>43</sup> but the literature on the effects of UMP on the bubble component of asset prices is relatively scarce and the results are mixed. Among the existing studies, Blot, Hubert, and Labondance (2020b) do not find evidence of a significant effect of expansionary monetary policy on indicators of stock price bubbles, suggesting that monetary policy does not represent a threat to financial stability. However, Hudepohl, Lamoen, and Vette (2019), using the GSADF-test, a recent advances in bubble detection techniques, show that the announcement and the start of asset purchase programs in the euro area led to an exuberant increase in stock prices in several countries, even after controlling for improving fundamentals.

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<sup>43</sup>See, for example, Gagnon, Raskin, Remache, and B. P. Sack 2011; D’Amico and King 2013; Li and Wei 2013 for the U.S., M. A. S. Joyce et al. 2011 for the U.K., and Breckenfelder et al. 2016; Eser et al. 2019 for the euro area.

Third, some studies explicitly assess the side effects of UMP on financial stability, by assessing its impact on several financial instability indicators and transmission channels. Lewis and Roth (2019) show that ECB’s asset purchase programs increase market volatility, liquidity risk and contagion risk putting therefore financial stability in danger. In contrast, Beck, Duca, and Stracca (2019) find no evidence of side effects and increased risk-taking as a result of QE, with real house prices and real credit neither rising nor falling, or even effects on stock market volatility. Finally, Weale and T. Wieladek (2021) compare the financial effects of QE relative to those of conventional monetary policy in a Bayesian VAR model and show that there is no statistically significant difference across monetary policy tools as far as measures of financial "side effects" are concerned.

### **3 Data and identification strategy**

The originality of our work consists in assessing the various dimensions of monetary policy surprises for the ECB and the Fed. We therefore need to use methods that separate the different components of policy announcements. Following Gürkaynak, B. Sack, and E. Swanson (2005), and Altavilla et al. (2019), we apply principal component analysis to the changes in various market interest rates at the time of the ECB and Fed policy announcements in order to extract factors that explain most of the variation of these rates around the chosen time window. Compared to the existing literature, our contribution consists in the estimation of a new set of factors that explicitly distinguish between private and public asset purchase programs.

#### **3.1 Data**

We study asset-price changes around 85 FOMC announcements from January 2008 to December 2017 using an updated version of the Gürkaynak, B. Sack, and E. Swanson (2005) dataset. For the euro area, we study asset-price changes around 129 announcements from the ECB Governing Council, from January 2008 to December 2018 using the Euro Area Monetary Policy Event-Study Database (EA-MPD) of Altavilla et al. (2019).

These two datasets are similar in that they include all monetary policy events of both central banks. The Gürkaynak, B. Sack, and E. Swanson (2005) database contains the surprises of intra-

daily quotes of federal funds futures, eurodollar futures, Treasury bond yields, the S&P500 and exchange rates, in a thirty-minute window around the Federal Open Market Committee (FOMC) statements. The window begins 10 minutes before the FOMC announcement and ends 20 minutes after. The EA-MPD is also a compendium of price/yields changes for a wide range of assets: Overnight Indexed Swaps (OIS), sovereign bond yields (German, French, Italian and Spanish) as well as exchange rates and stock price indices. A surprise is defined as the difference between the median quote 10 minutes before and 10 minutes after a specified time window. The database is available for three different windows regarding the communication of ECB's monetary policy decisions: (i) the press release, (ii) the press conference, and (iii) the full monetary policy event window. We only use the third window in our study.

Our contribution is to add to these datasets a variable allowing us to disentangle public asset purchase programs from private ones: the Investment Grade corporate bond spread. We add its daily variation of around each monetary policy event as there are very small intra-daily variations of this variable. For the U.S., we use the Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity (FRED - Federal Reserve Bank of St. Louis). For the euro area, we construct the corporate bond spread with the ICE BofA BBB Euro corporate index 10 years (Bloomberg) and the 10 years Overnight Index Swap (OIS). We consider that the 10 years OIS is a better indicator of the euro area risk-free rate than the German government yield because the later was affected by the euro area sovereign crisis from 2009 until the mid to late 2010s. Using this two databases, we extract four orthogonalised and independent factors: (i) The "target", (ii) the "forward guidance" factor, (iii) the "public QE" factor and (iv) the "private QE" factor. Each of them captures a different type of monetary policy surprise and can be interpreted independently from the other factors.

### 3.2 Identification strategy

The two datasets are composed of asset price responses into a  $T \times n$  matrix  $X$ , with rows corresponding to central bank announcements and columns to different asset classes. Each element  $x_{ij}$  of  $X$  then reports the 30-minute response (for the Fed) and the 20-minute response (for the ECB)

of the  $j_{th}$  asset to the  $i_{th}$  central bank announcements.

As in Gürkaynak, B. Sack, and E. Swanson (2005), Swanson (2021) or Altavilla et al. (2019), we can think of these data in terms of a factor model:

$$X = F\Lambda + \epsilon \quad (13)$$

Where  $F$  is a  $T \times k$  matrix containing  $k \leq n$  unobserved factors,  $\Lambda$  is a  $k \times n$  matrix of loadings of asset price responses on the  $k$  factors, and  $\epsilon$  is a  $T \times n$  matrix of white noise residuals that are uncorrelated over time and across assets. If  $k = 0$ , the data  $X$  would be well described by  $n$  uncorrelated white noise processes; if  $k = 1$ ,  $X$  would be well described as responding linearly to a single factor plus uncorrelated white noise.

Using this factor model, we are interested in uncovering how many factors, i.e. how many dimensions of monetary policy, are needed to satisfactorily describe the Fed and the ECB monetary policy announcements. The number of such factors are often referred to as latent variables, i.e. variables that are not directly observable but assumed to affect the response variables  $X$ . The set of orthogonal factors  $F_i$  with  $i = 1, \dots, k$  are decomposed from  $X$  in such a way that Factor 1 ( $F1$ ) accounts for as much of the variability as possible of  $X$ .  $F2$  is the factor that has maximum explanatory power for the residuals of  $X$  after estimating  $F1$ , and so on.

The factor estimation methodology follows Swanson (2021) and relies on a factor rotation procedure. For the U.S., we take  $X$  to include 15 variables<sup>44</sup> including notably the 1st and 3rd federal funds futures contracts, the 3rd, and 4th Eurodollar futures contracts<sup>45</sup>, the 2-, 5-, and 10-year Treasury yields. We add the corporate bond spread to distinguish public asset purchase programs from private ones. For the euro area, we also include 15 variables in the matrix  $X$ : the 1-, 3-, 6-months OIS, the 1-year OIS, the 2-, 5-, 10-year Italian sovereign yields and the corporate bond

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<sup>44</sup>We tried with a larger (20 variables) or smaller number (8 variables) of variables and the results were quite similar, thus confirming their robustness.

<sup>45</sup>Futures contract whose underlying asset is a Eurodollar time deposit that has a principal value of \$1 million with a three-month maturity

Table 5: U.S.- Variance explained by the first four factors

Factor	<b>Variance</b>	<i>Cumulative</i>	<b>Proportion</b>	<i>Cumulative</i>
F1	<b>8.26</b>	<i>8.26</i>	<b>0.59</b>	<i>0.59</i>
F2	<b>2.04</b>	<i>10.30</i>	<b>0.15</b>	<i>0.74</i>
F3	<b>1.48</b>	<i>11.78</i>	<b>0.11</b>	<i>0.84</i>
F4	<b>1.00</b>	<i>12.78</i>	<b>0.07</b>	<i>0.91</i>

Notes: This table reports the variance explained by the four different factors as well as the proportion of the total variance explained by each of them. In italics, the percentage of variance explained is cumulated of the four factors.

spread. We use Italian sovereign yields instead of German sovereign yields as Italian rates are a good indicator of the fragmentation of monetary policy transmission in the euro area.

Following Swanson (2021), the choice of the main variables included in  $X$  is explained as follows:

- The 1st and 3rd federal funds futures contracts and the 1-, 3-months OIS for the euro area provide good estimates of the market expectations of the federal funds rate and the main refinancing operations (MRO) rate after the current and next central banks meetings.
- The 3rd, and 4th Eurodollar futures contracts and the 6-months OIS and the 1-year OIS for the euro area provide information about the market expectation of the path of the short-term interest rate in the medium term.
- The 2-, 5-, and 10-year Treasury yields (and the 2-, 5-, 10-year Italian yields) provide information about interest rate expectations and risk premia over longer horizons, out to 10 years.
- Finally, the corporate bond spread provide information on market expectations related to corporate yields.

Our factor analysis shows that the data are well explained by four factors, i.e. four separate dimensions of monetary policy. As shown in tables 5 and 6, four factors explain around 91% of the variance in the U.S., and 96% in the euro area, and each of these factors contributes at least 5%. It seems consistent with the fact that monetary policy announcements contain information about

Table 6: EA - Variance explained by the first four factors

Factor	<b>Variance</b>	<i>Cumulative</i>	<b>Proportion</b>	<i>Cumulative</i>
F1	<b>5.85</b>	<i>5.85</i>	<b>0.41</b>	<i>0.41</i>
F2	<b>5.07</b>	<i>10.91</i>	<b>0.37</b>	<i>0.77</i>
F3	<b>1.91</b>	<i>12.82</i>	<b>0.13</b>	<i>0.91</i>
F4	<b>0.75</b>	<i>13.57</i>	<b>0.05</b>	<i>0.96</i>

Notes: This table reports the variance explained by the four different factors as well as the proportion of the total variance explained by each of them. In italics, the percentage of variance explained is cumulated of the four factors.

several monetary policy tools, especially since the introduction of UMP. As our four dimensions of monetary policy, we think of the following policies<sup>46</sup>:

1. **Target**: captures the surprises of an unexpected change in the official rates and therefore corresponds to a conventional monetary policy shock.
2. **Forward guidance**: reaction of market participants to statements referring the commitment from the central bank to particular monetary policy actions.
3. **Public quantitative easing** (Public QE): reaction of markets regarding announcements and news about the introduction and implementation of public securities purchase programs.
4. **Private quantitative easing** (Private QE): reaction of markets regarding announcements and news about the introduction and implementation of private securities purchase programs<sup>47</sup>.

We will focus on this interpretation of the four monetary policy dimensions. However, it is important to mention that some authors might argue that other aspects of monetary policy are even more important. For example, there is a growing literature that emphasizes the role of information frictions in the monetary transmission mechanism (Miranda-Agrippino and Ricco 2021; Jarociński and Karadi 2020; Nakamura and Steinsson 2018; Andrade and Ferroni 2021). Information shock, also known as Delphic forward guidance (Campbell et al. 2012) corresponds to news about the central bank’s private macroeconomic outlook. This dimension is however beyond our research

<sup>46</sup>See Appendix B.1 for the description of these policies.

<sup>47</sup>ABS, covered bonds, corporate bonds for the ECB and MBS for the Fed.

question.

The four factors estimated above are only a statistical decomposition and do not have any structural interpretation. In order to interpret the extracted factors, we must find a unique rotation matrix that fulfils a set of restrictions with an economic meaning. Then, once we have applied a rotation to the factors, we must verify their relevance. For example, regarding the U.S. private QE factor, it must correspond to FOMC announcements about MBS bond purchases. Moreover, the rotated factors explain the variability in matrix  $X$  to exactly the same extent as the unrotated factors. And because the unrotated factors are orthogonal by construction, the rotated factors remain also orthogonal.

While technical details about the restrictions on the rotation matrix are described in Appendix B.2, we focus here on the rationale behind our identifying assumptions. First, following Gürkaynak, B. Sack, and E. Swanson (2005), Swanson (2021) or Altavilla et al. (2019), we restrict the one-month-OIS loadings (and the federal fed funds futures for the U.S.) to zero for the (i) forward guidance, (ii) the public quantitative easing and (iii) the private quantitative easing factors. The rationale behind this is that forward guidance and quantitative easing are implemented in order to influence only medium and long term rates. Only the "Target" factor can have an influence on short-term interest rates.

Second, as the main objective of our paper is to disentangle private asset purchase programs from public ones and highlight the difference in their effects on financial stability, we must find restrictions allowing the distinction between the two. Using a sign restriction approach applied to factor identification, as detailed, for instance, in Eickmeier, Gambacorta, and Hofmann (2014), we impose that public QE, aiming at lowering the 10-year Treasury yields, should also lead to an increase in corporate bond spreads (its impact on public bonds being larger than on private ones), while private QE should have negative effects on corporate bond spreads.

Table 7: U.S. - Estimated effects of monetary policy announcements on interest rates

	MP1	MP2	ED3	ED4	ONRUN2	ONRUN5	ONRUN10	BAA
Target	0.97	0.92	0.42	0.30	0.29	0.06	-0.03	-0.001
Forward guidance	0.00	0.10	0.32	0.31	0.56	0.62	0.55	-0.29
Public QE	0.00	-0.06	-0.44	-0.55	-0.56	-0.74	-0.64	0.49
Private QE	0.00	-0.14	-0.25	-0.17	0.03	0.31	0.41	-0.30

Notes: The values reported in this tables correspond to the elements of the structural loading matrix  $\tilde{\Lambda}$ , in percentage per standard deviation change in the monetary policy instrument. MP1 and MP2 denote scaled changes in the first and third federal funds futures contracts, respectively; ED3, and ED4 denote changes in the third and fourth Eurodollar futures contracts; ONRUN2, ONRUN5, and ONRUN10 denote changes in 2-, 5-, and 10-year Treasury yields and BAA the change in the corporate bond spread.

The hypothesis on the effects of private QE on corporate spreads is supported theoretically and empirically. Purchases of assets with some private risk component might decrease corporate bond yields more than Treasury yields due to the greater similarity of the former asset with corporate bonds (Swanson 2021). The theoretical foundation of this constraint is the preferred habitat model which predict a larger impact of private asset purchases on other private assets such as corporate bonds, if investors' motives are not determined by their maturity or duration preference, but by other risk characteristics. This assumption is also supported by the empirical literature. Regarding the euro area, for example, Zaghini (2019) shows that the implementation of the CSPP in March 2016 led to a decline in corporate bond spreads. More precisely, spreads on eligible bonds declined faster than those on non-eligible bonds, suggesting a larger improvement in the funding conditions for investment-grade firms. In the U.S., Krishnamurthy and Vissing-Jorgensen (2011) highlight the fact that the effects on particular assets highly depends on the type of assets purchased by the central bank. LSAP1, characterized by MBS purchases, were crucial for lowering MBS yields as well as corporate yields contrary to LSAP2 (Treasury purchases).

Table 7 and 8 show the loading matrix  $\tilde{\Lambda}$  (see Annex B.2) that results from the identifying assumptions presented above. Each rotated factor is normalized to have a unit standard deviation, so the coefficients in the table are in percentage per standard deviation change in the monetary policy instrument. We can see the different identifying assumptions in the tables: the forward guidance, the public quantitative easing and the private quantitative easing factors have no effect on the first



Table 8: EA - Estimated effects of monetary policy announcements on interest rates

	OIS1M	OIS3M	OIS6M	OIS1Y	IT2Y	IT5Y	IT10Y	BBB
Target	0.95	0.98	0.92	0.82	0.50	0.22	0.03	0.06
Forward guidance	0.00	0.15	0.34	0.54	0.70	0.63	0.46	0.14
Public QE	0.00	-0.08	-0.06	-0.09	-0.38	-0.73	-0.43	0.22
Private QE	0.00	-0.13	-0.29	-0.47	-0.61	-0.57	-0.51	-0.57

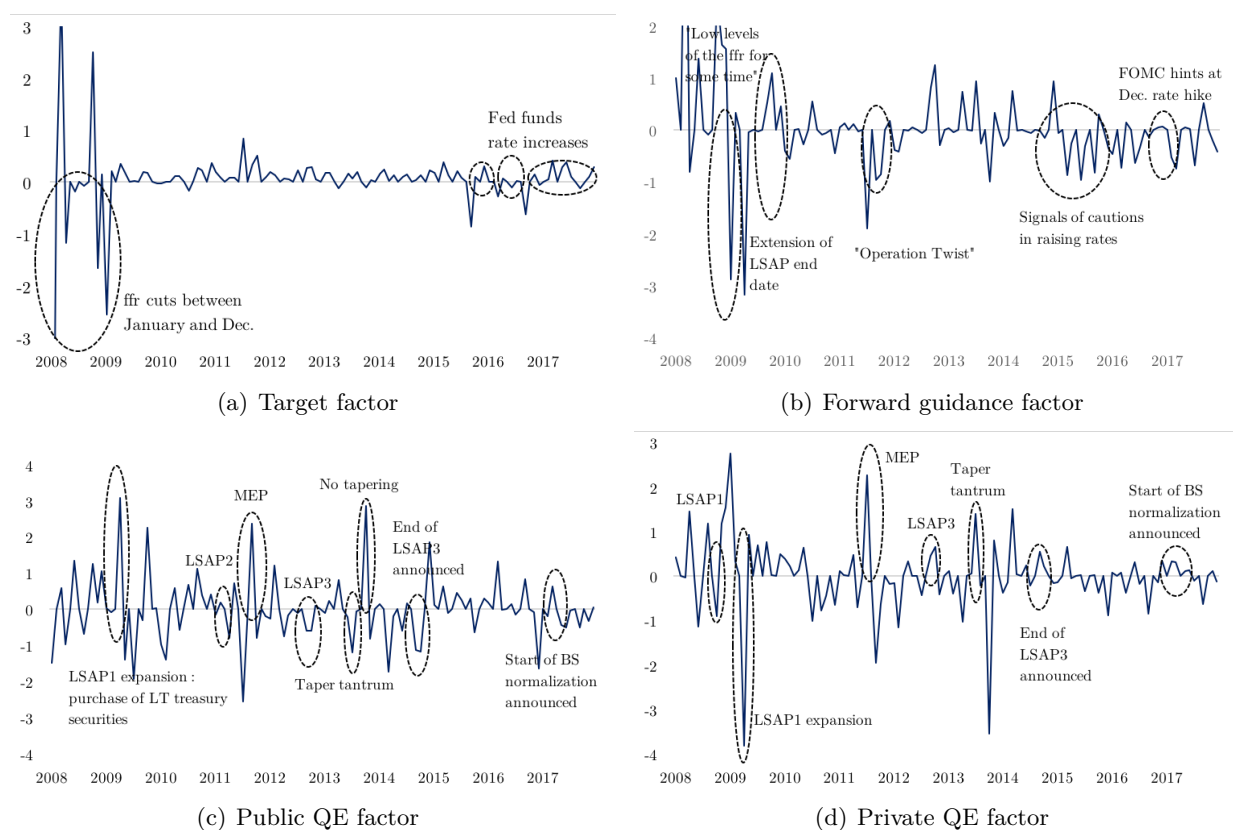
Notes: The values reported in this tables correspond to elements of the structural loading matrix  $\tilde{\Lambda}$ , in percentage per standard deviation change in the monetary policy instrument. OIS1M and OIS3M denote scaled changes in 1 and 3-months OIS ; OIS6M and OIS1Y denote changes in the 6-months OIS and the 1-year OIS ; it2Y, it5Y, it10Y the change in 2-,5-, and 10-year italian yields ; and BBB denotes the change in the corporate bond spread.

federal funds futures contracts for the U.S. and on the 1-month OIS for the euro area (1st column). Moreover, private QE (public QE) leads to a decrease (increase) in the corporate bond spread (4th column). The target factor, in the first row, loads more significantly on short term assets and reflects information about the current target rate. The impact diminishes as maturities increase, proving the ineffectiveness of the conventional monetary policy in influencing long rates after the global financial crisis. The effects of forward guidance, in the second row of these two tables, are also consistent with the estimates of Gürkaynak, B. Sack, and E. Swanson (2005), Swanson (2021). By construction, a shock to the forward guidance factor has no effect on the shorter maturity rate. The effects increase at longer maturities, peaking at a horizon of about one year for the U.S. and 2 years for the euro area. Then, the impact diminishes slightly. As far as the separation between the private and the public QE factors, we need to check whether their effects on interest rates are different and in line with expectations. First, the opposite effect of these two factors on the corporate bond spread are explained by our identifying restrictions. Second, the effect of public QE on sovereign yields is negative at the various maturities (2, 5 and 10 year). This is in line with Krishnamurthy and Vissing-Jorgensen (2013), for example, who find that LSAPs have a substantial impact on longer-term Treasury yields. Third, while the private QE has more or less the same (negative) impact on sovereign yields in the euro area than the public QE, its effect on the U.S. Treasury yields is slightly positive. This is consistent with the cross-sectional effects of these instruments, i.e. the fact that one specific program may more sharply affect prices relevant to particular sectors of the economy. With the MBS purchases, the Fed has the explicit intention to

lower the spread between mortgages and Treasury debt, in order to provide stimulus to the housing sector.

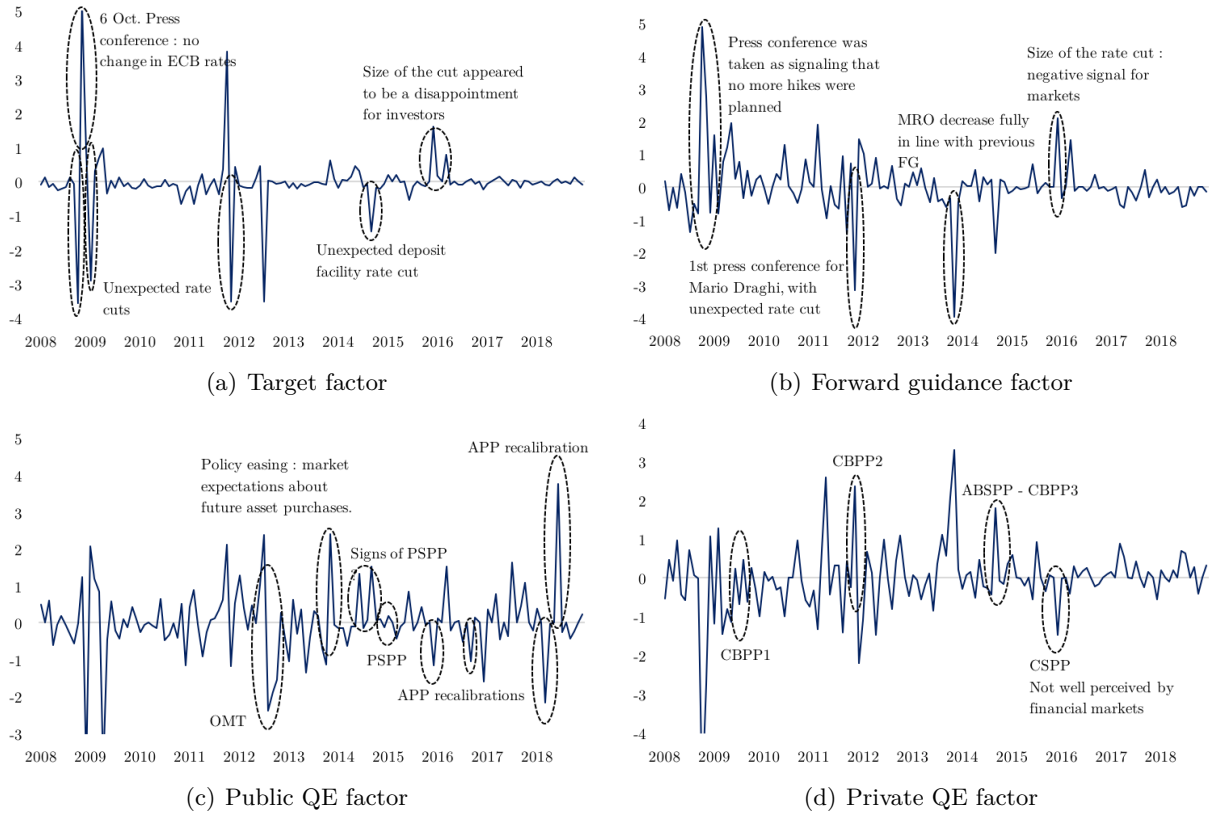
Overall, the results of tables 7 and 8 seem to show that our identifying assumptions are reasonable and that the identified factors do correspond well to these four dimensions of monetary policy: target, forward guidance, public QE and private QE.

Figure 14: Estimated factors and monetary policy announcements in the U.S.



Notes: The blue line represent the full-sample estimate for each factors. ffr (Fed funds rate), LSAP (large-scale asset purchases), MEP (Maturity Extension Program), BS (balance sheet), Taper Tantrum (unexpected reaction from investors to the Fed to reduce its bond purchases).

Figure 15: Estimated factors and monetary policy announcements in the euro area



Notes: The blue line represent the full-sample estimate for each factors. MRO (Main Refinancing Operations rate), OMT (Outright Monetary Transactions), APP (Asset Purchase Programme), PSPP (public sector purchase programme), CBPP (covered bond purchase programme), ABSPP (asset-backed securities purchase programme).

Figures 14 and 15 show how well our four estimated factors for the U.S. and the euro area correspond to the Fed and ECB monetary policy announcements (January 2008 to December 2017 for the U.S., and January 2008 to December 2018 for the EA). The blue line represent the full-sample estimate for each factors. Positive (negative) values of the target factor and the forward guidance factor correspond to monetary policy tightening (easing) and positive (negative) values of the public QE and the private QE factors to monetary policy easing (tightening). We observe that our different factors seem to correspond to monetary policy announcements. For example, for the United-States, we can observe that the public QE factor reacts positively to the announcement of the LSAP1 expansion in March 2009 (loosening monetary policy announcement).

## 4 Assessing the impact of monetary policy surprises on financial stability indicators

To study the persistence of the effects of monetary policy surprises on financial stability, we use the estimated factors as exogenous shocks in a local projection (LP) framework (Jordà 2005). Since our factors were constructed as time series for each central bank’s announcement, it is necessary to first convert them to monthly frequency to use them at monthly frequency in our empirical methodology. We follow the approach from Eberly, Stock and Wright (2019) and simply convert the factors by creating monthly measures that are equal to the factor in months with announcements, and equal to zero in months without announcements. LPs consist in running a sequence of forecasting regressions of our dependant variable on the monetary policy shocks for different prediction horizons.

$$Y_{t+h} = \beta_h shock_t + \sum_{i=1}^P \zeta_{i,h} X_{t-i} + \epsilon_{h,t+h} \quad (14)$$

For all  $h = 1, \dots, 24$ , where  $Y_{t+h}$  is our dependant variable (the SRISK indicator and the asset price bubble indicator),  $shock_t$  corresponds to our four monetary policy shocks,  $\epsilon_{h,t+h}$  is a vector of residuals at horizon  $h$ , and  $X_{t-i}$  the vector of control variables where we set  $p = 4$ . It contains the lagged values of the dependant variable to control of serial autocorrelation and other control variables, namely the consumer price index, the production index and the VIX<sup>48</sup> (or VSTOXX<sup>49</sup> for the euro area).

We estimate equation (2) by using the Smooth Local Projection (SLP) method recommended by Barnichon and Brownlees (2019). It consists of reducing the excess of variance of the estimates of  $\beta_h$  related to the LP method estimated by Ordinary Last Squares (OLS). Precisely,  $\beta_h$  is approximated by applying a linear B-spline basis function and the impulse response function is smoothed through a smoothing parameter. Therefore, the SLP method preserves the flexibility of LP (Jordà

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<sup>48</sup>The Cboe Volatility Index, or VIX, is a real-time market index representing the market’s expectations for volatility over the coming 30 days.

<sup>49</sup>The VSTOXX index tracks the expected 30-day volatility of the EURO STOXX 50 equity index.

2005) while offering efficiency gains by imposing that impulse responses are polynomial functions of the forecast horizons. We estimate the model over the sample period 2008M1 through 2017M12 for the U.S. and 2008M1 through 2020M6 for the euro area.

#### **4.1 A Closer look at our two financial stability indicators**

Regarding our financial stability indicators, we use the aggregate SRISK, which measures the capital shortfall of a financial institution conditional on a severe market decline, as well as a measure of equity market overvaluation. The SRISK indicator (figure 16) is mostly used to identify systemically important financial institutions (SIFIs) at micro-level (Banulescu and Dumitrescu 2015; Benoit, Hurlin, and Perignon 2015), but there already exist a growing number of studies using this indicator as a proxy for aggregate systemic risk at aggregate level in the financial system (R. Engle, Jondeau, and Rockinger 2015; Langfield and Pagano 2016; Colletaz, Levieuge, and Popescu 2018). At the individual level, the SRISK corresponds to “the expected capital shortfall of a given financial institution, conditional on a crisis affecting the whole financial system” (Benoit, Colliard, et al. 2017). This measure combines an economic analysis of V. Acharya et al. (2017) and an econometric model developed by Brownlees and R. Engle (2012). The main features of the SRISK indicator are presented in Tavoraro and Visnovsky (2014). This measure is based exclusively on publicly available information (market and accounting data): the market capitalization of firms, their financial leverage and data related to the sensitivity of the equity return to market shocks. Therefore, it accounts not only for the size of the institution and its individual risk, but also for the correlations between the market and the firm’s return. It hence takes into account the two main components of systemic risk: size and interconnectedness (Colletaz, Levieuge, and Popescu 2018). The idea behind the aggregate measure of systemic risk, which is common to use in the systemic risk literature, is that the total amount of capital that would be needed to bail out the financial system, if a financial crisis were to occur, is the sum of all the capital needed by each institution. The aggregate SRISK can be thought of as a stress test on the financial system, where the adverse case scenario is defined as a 40% decrease in global equity market over a 6-month time horizon (Engle and Zazzara 2018). This aggregate SRISK is based on four types of financial firms:

banking institutions, insurance companies, financial services and real estate firms. According to Deev and Hodula (2016), who evaluate the performance of three systemic risk measures for the euro area (SRISK, CISS and term-spread) using combination of Markov-switching models and dynamic conditional correlation models, the SRISK indicator seems to identify successfully the accumulation phases that might eventually lead to financial instability.

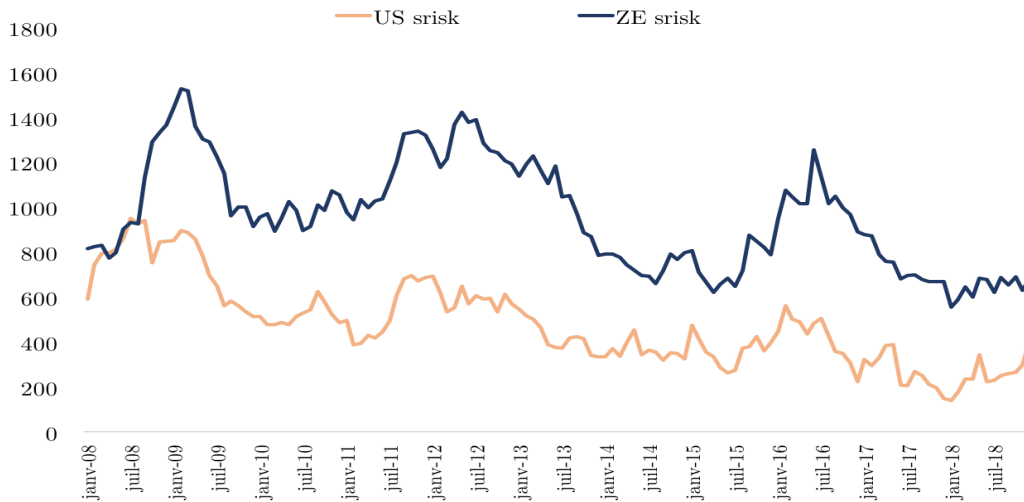


Figure 16: SRISK indicator in the U.S. and in the EA (01.2008 - 12.2008)

Regarding our measure of asset price bubbles (figure 17), there are several methods to detect it and no consensus on the most effective one. Filardo (2004) defines an asset price bubble as a situation in which “an asset price tends to grow persistently out of line with fundamentals, often in a frothy way, and tends to end unexpectedly with a sharp correction”. While the price of a stock is observable in the market, we do not observe its fundamental value. As such, any method used to identify asset price bubbles needs to find a way to estimate the stock’s fundamental value. In this paper, we choose to summarize the information of three bubble detection methods in a composite indicator<sup>50</sup>. This allows to take into account the uncertainty around these different identification methods and to obtain a common component, which can be considered as a robust indicator of stock price bubbles. The first bubble detection method is based on the discounted cash-flow model (DCF) in which the fundamental value of a security is equal to the sum of expected discounted

<sup>50</sup>Blot et al. use this methodology to identify the bubble component of asset prices in the U.S. between 1987 and 2019.

future cash-flows (dividends for share prices). The bubble component is then identified as the difference between the current price of a stock index (S&P500 for the U.S. and EURO STOXX 50 for the euro area) and its estimated fundamental component, calculated with the DCF model. We use as a discounted rate the U.S. 10 Year Treasury and the German 10 Year Government Bond for the euro area, plus a proxy of risk premium (VIX for the U.S. and VSTOXX for the euro area). Under the second approach, we estimate a model where the stock price index is explained by the following macroeconomic and financial variables at time  $t$ : GDP, inflation, real interest rate, VIX (VSTOXX for the euro area), dividends, M2, credit, consumer and firm confidence indicators, house price, oil price, real disposable income. The idea is that all of these macroeconomic and financial variables allow to calculate the fundamental value of a stock. The difference between the market price and the fundamental value corresponds to the bubble component of the price. Indeed, the asset price bubble indicator is captured by the residuals of a simple OLS regression, in which the dependant variable (S&P500 or stoxx50) is explained by these variables. The third method simply consists of identify deviations from a statistical trend. Finally, we summarize the information of these three methods in a composite indicator by using a principal-component analysis (PCA). The first principal component corresponds to the common denominator of the three approaches (figure 17).

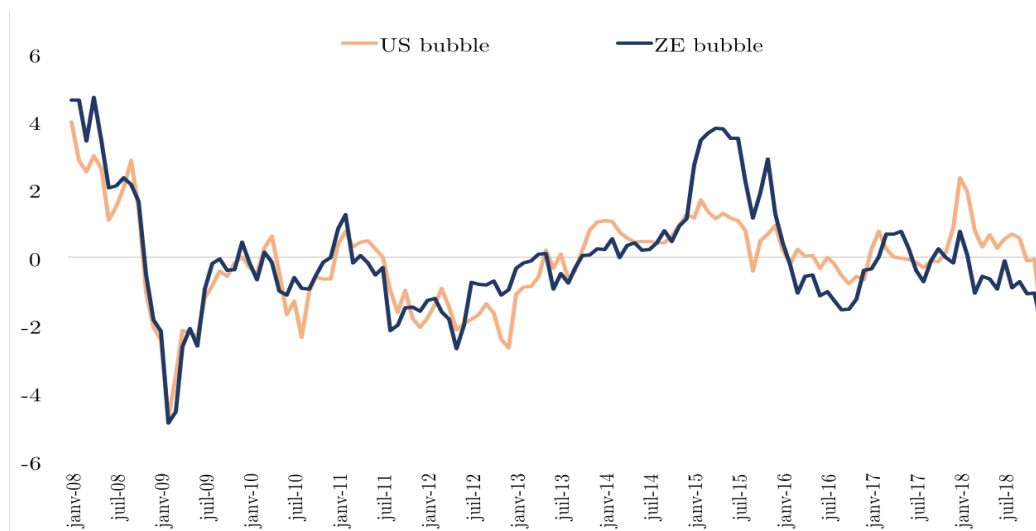


Figure 17: Asset price bubbles indicator in the U.S. and in the EA (01.2008 - 12.2008)

## 4.2 Main Results

Figures 18, 19, 20, and 21 plot the impulse responses (IRs), obtained from SLPs, of the SRISK indicator and the bubble indicator to a one standard deviation monetary policy shock, respectively the target, the forward guidance, the public QE, and the private QE shocks in the U.S. Indeed, the target and the forward guidance shocks correspond to tightening monetary policy surprises and the public QE and the private QE shocks, to expansionary shocks. Figures 22, 23, 24 and 25 reports the same IRs for the euro area. The blue dash-dotted lines around the IRs represent 95% and red dashed lines 68% confidence intervals. The horizon for the responses in the figures is 24 months.

In the U.S., following a contractionary target surprise, the SRISK decreases on impact and continues to decrease during 8 months thereafter. Then, it increases between the 10th and 20th month after the initial shock. This second finding can be explained by the fact that a higher Fed funds rate causes the amount of capital needed by a financial firm in the event of a crisis to raise, resulting in a higher SRISK. The decrease in the SRISK following the target surprise in the euro area occurs much later and continues until the end of our horizon. Therefore, it indicates a short-term stabilising effect of a restrictive conventional monetary policy in the U.S. and a medium/long-term one in the Eurozone. This negative effect of a rise in the short-term rate on systemic risk is consistent with the risk-taking channel theory, according to which very low interest rates distort risk perception, increase leverage and reduce bank monitoring (Borio and Zhu 2008). Conversely, tighter monetary conditions are likely to gradually reduce leverage in the financial sector (Dell Ariccia, Laeven, and Marquez 2014). Moreover, by reducing search-for-yield motives, higher rates should reduce risk-taking by financial institutions.

The target factor tends to strongly and persistently reduce the bubble factor in the stock market (figure 20). This results are consistent with those of Blot, Hubert, and Labondance (2020b) who find that restrictive monetary policies (including all monetary policy instruments) have large negative effects on asset price bubbles. Beckers and Bernoth (2016) find also a significant decline in the mispricing component of stock prices following monetary policy tightening (only half of the impact response in stock prices can be attributed to changes in expectations about future dividends, the



discount factor, and the equity premium). In the euro area, the bubble measure shows a slight and rapid decline following the tightening shock. These findings are in line with the literature, i.e. it has been demonstrated that a shock of the opposite nature (decrease in the central bank interest rate) can compress the risk premia in asset prices, leading to excessive valuations and sometimes asset price bubbles. One interesting finding here is the difference of intensity in the reaction of the bubble indicator in the U.S. and in the euro area to the same monetary policy shock. This is most likely due to a greater sensitivity of the bubble indicator in the U.S. related to the structure of its financial system (capital market-based system). It demonstrates the better efficiency of the “leaning against the wind” (LATW) theory (Lowe and Borio 2002; Cecchetti, Genberg, and Wadhwani 2002) in the U.S. The LATW policy prescription builds on the conventional view that an increase in interest rates reduces the size of an asset price bubble.

The next monetary policy surprise under consideration (figure 21 and 25) is a tightening forward guidance surprise. We find that the SRISK decreases between the 16th and the 18th month after the shock in the U.S. (if we consider the 95% confidence interval). It declines faster and to a larger extent in the euro area (between the 7th and the 17th after the tightening forward guidance shock). These declines of the SRISK can also be justified by the presence of the risk-taking channel. In a similar way to the target factor, a commitment to a protracted period of very low interest rates (accommodative forward guidance) could encourage risk-taking as investors search for yield, lead to a build-up in leverage, and lead lenders to lower their credit standards and promote increased borrowing. By contrast, a tightening forward guidance is therefore supposed to lead to the opposite effects, either a decrease in systemic risk.

The asset price bubbles indicator declines in the very short-term in the U.S. and in the euro area. These findings seem to describe Odyssean forward guidance surprises, defined as news on future monetary policy shocks (Campbell et al. 2012). In a similar way, Campbell et al. (2012) show that unexpected increases in short-term interest rates on the days of policy meetings have a negative impact on stock prices. In the medium-term in the U.S., the bubble indicator reacts positively to the forward guidance surprise. This finding could be explained by the fact that markets interpret

this tightening monetary policy action as a signal of a better macroeconomic outlook, better current and future demand conditions (Delphic forward guidance, Campbell et al. (2012)). Therefore, this can lead to the opposite effect of what was intended by the central bank (given the existence of the inverse relationship between the interest rate and asset prices), i.e. an increase in the bubble component of asset prices.

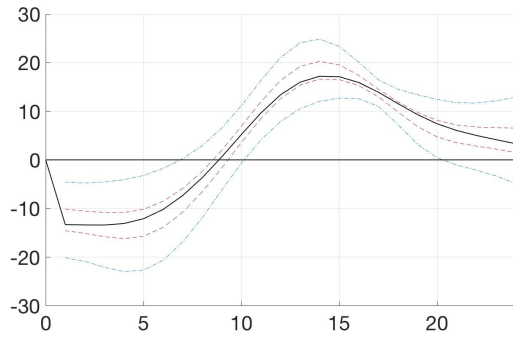
Figure 20 and 24 report the responses of the SRISK and the bubble indicator to a public quantitative easing surprise, respectively in the U.S. and in the euro area. In the U.S., we can first observe a significant decrease in the SRISK indicator on impact which continues to decrease during 8 months thereafter. This positive effect on financial stability can be explained by the provision of new liquidity, the resolution of dysfunctional markets and the reduction of uncertainty. In the medium run, this accommodative monetary policy surprise leads to the increase in the SRISK. The same surprise in the euro area also leads to the rise of the SRISK, but the increase is longer lasting. These results highlight the effectiveness of these public asset purchase programs. Indeed, the risk-taking channel is one of the transmission channel that make quantitative easing effective. This instrument aims at reducing long-term interest rates in order to spur economic growth by increasing the supply of loans. This lead to a search for yield behavior from financial institutions to maintain their profit level. Moreover, the liquidity injections can translate into a credit expansion through lower credit standards from financial intermediaries. The potential increase in systemic risk lies in the excessive nature of this behavior. In the results, we can however observe that in the longer run, the effects become insignificant, even negative for the U.S. The increase in risk-taking from financial institutions is temporary and therefore does not appear to pose any threat to financial stability.

In the U.S., the bubble indicator increases during the first three months after the shock and very slightly decreases between the 14th and the 17th months after the shock. In the longer term, from the 17th month after the shock, public QE no longer has an effect on the bubble indicator. For the euro area, the public QE shock leads to a slight increase in the bubble indicator a few months after the shock, although, again, this positive effect is only transitory. Thus, in the long term, public

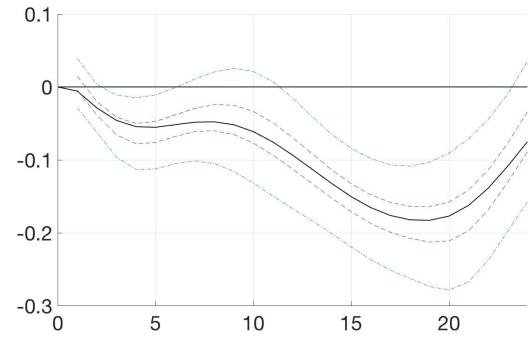
assets purchased programs do not spur any sign of equity market overheating. These programs even have a stabilising effect in the medium term in the U.S.

Next, we examine the effects of an expansionary private quantitative easing shock. For our two areas, the accommodative private QE shock leads to the increase in the SRISK (during the seven first months after the shock for the U.S. and between the 7th and the 18th for the euro area). As for the public QE factor, it demonstrates the effectiveness of these programs as the risk-taking channel is one of the transmission channel of this monetary policy instrument. Private asset purchase programs are even supposed to push the risk-taking of financial actors even further. Indeed, the idea is that investors, facing a scarcity of bonds purchased by the central bank, are encouraged to reallocate their holdings to other, riskier, assets. Overall, it leads to a reduction in borrowing costs for most firms. In the long term, this expansionary monetary policy shock contributes to reinforce financial stability in the U.S., as it decreases the SRISK from the 27th month after the shock. In the euro area, it does not improve financial stability but the effect of private QE on the SRISK becomes insignificant.

The asset price bubbles index increases in the very short term and in the medium run in the euro area before becoming totally insignificant. However, in the U.S., the private QE shock initially allows the bubble indicator to fall. And in the longer run, the indicator shows some transitory increase. Our findings shed light on the fact that accommodative policies, whether conventional or unconventional, generate some increase in systemic risk, but these effects remain transitory and therefore do not raise strong concerns about financial stability.

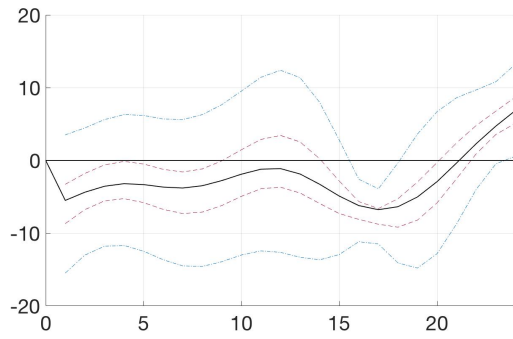


(a) Srisk

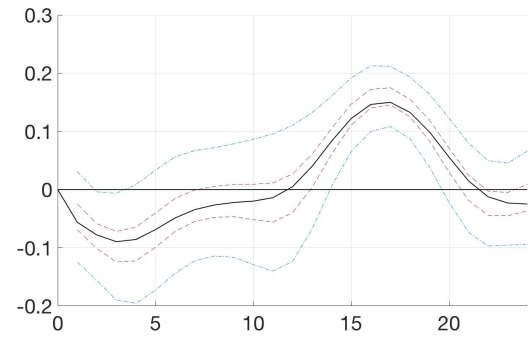


(b) Bubble indicator

Figure 18: U.S. - Effects of conventional monetary policy

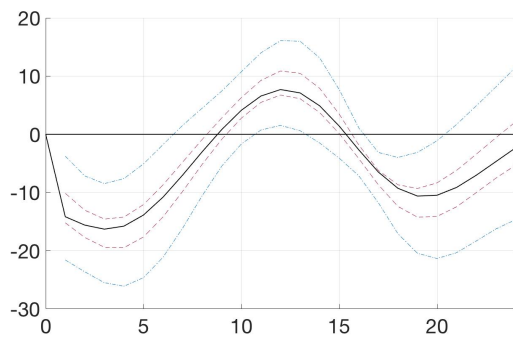


(a) Srisk

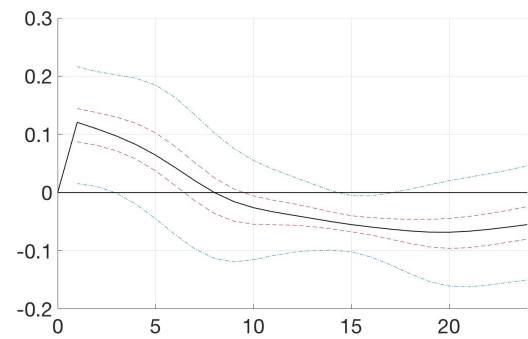


(b) Bubble indicator

Figure 19: U.S. - Effects of forward guidance

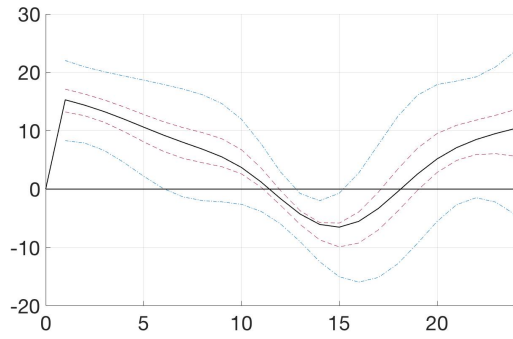


(a) Srisk

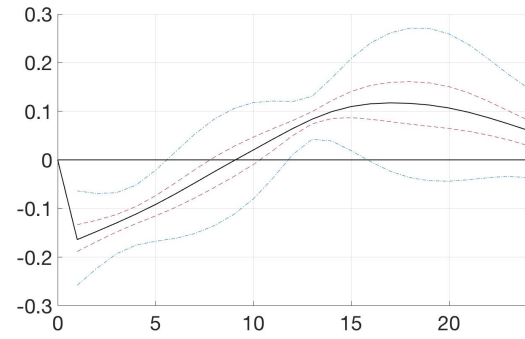


(b) Bubble indicator

Figure 20: U.S. - Effects of public quantitative easing

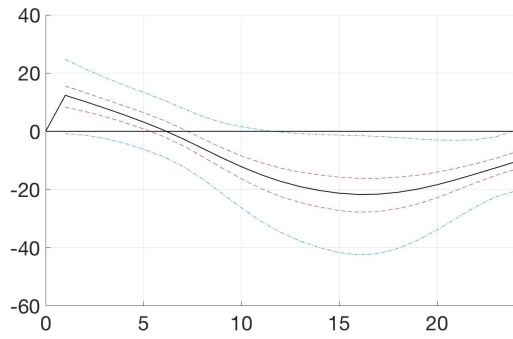


(a) Srisk

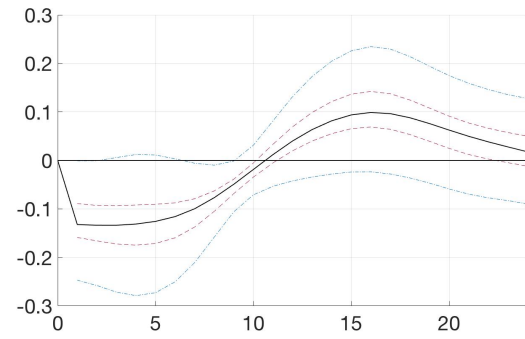


(b) Bubble indicator

Figure 21: U.S. - Effects of private quantitative easing

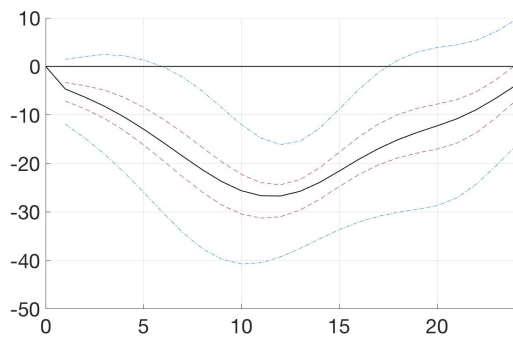


(a) Srisk

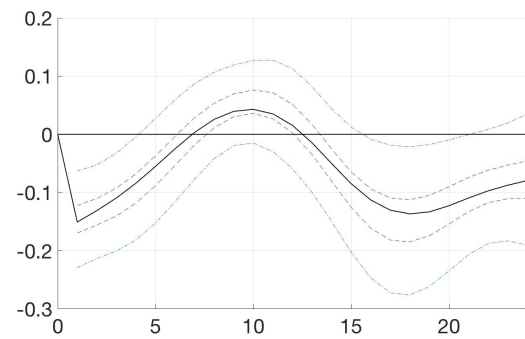


(b) Bubble indicator

Figure 22: Euro area - Effects of conventional monetary policy



(a) Srisk



(b) Bubble indicator

Figure 23: Euro area - Effects of forward guidance

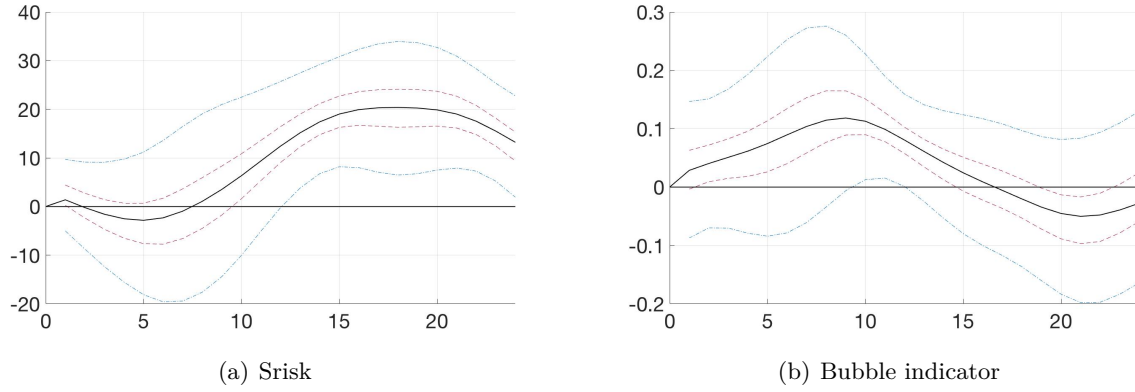


Figure 24: Euro area - Effects of public quantitative easing

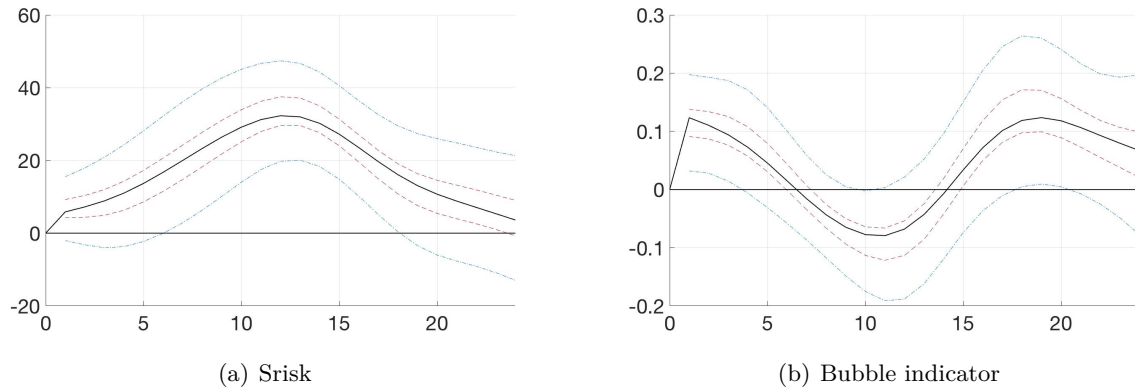


Figure 25: Euro area - Effects of private quantitative easing

### 4.3 Heterogeneity responses in the euro area to public QE shock

Having observed the effects of our different monetary policy surprises on two financial stability indicators in the U.S. and in the euro area, we now try to uncover whether these effects are equally transmitted through different countries of the euro area. We decide to focus on the reaction of the SRISK indicator to our four monetary policy shocks, because of the bank-based system of the euro area. The SRISK indicator is calculated by the V-Lab website for each euro area countries. We focus on four countries, France, Germany, Italy and Spain. Table 9 gives a quick overview of the cumulative purchases of securities under the PSPP by the National Central Bank (NCB) of the these four countries.

Table 9: Cumulative net central banks purchases of securities under the PSPP for France, Germany, Italy and Spain (Nov. 2021)

	Amount in billion euros	Relative to GDP (%)	Relative to public debt (%)	% of total purchases
France	488.536	21.2	18.4	19.8
Germany	580.224	17.2	24.9	23.5
Italy	411.197	24.8	15.9	16.7
Spain	292.880	26.1	22.3	11.9

Sources: ECB and authors' computations.

Table 10: Impulse response functions of SRISK to UMP shocks

		Target	Forward guidance	Public QE	Private QE
Italy	3 months	0.83**	-0.79**	-0.76*	0.69*
	12 months	-0.28**	-1.34**	1.10*	2.07**
	24 months	-2.98**	1.32**	2.12*	-2.03*
Spain	3 months	-1.37**	0.88**	0.44*	-0.57*
	12 months	-2.05**	0.79	4.44**	0.21*
	24 months	-0.92**	4.20**	0.45	-3.22**
France	3 months	-0.80**	-2.51**	0.10	1.88*
	12 months	-0.59**	-3.42**	3.96**	5.08**
	24 months	-7.29**	-0.89	2.37*	-0.48
Germany	3 months	1.98**	-0.90**	0.91*	1.13*
	12 months	-0.95**	-1.19**	1.04*	1.05*
	24 months	-4.92**	0.27	1.10*	-1.16*

Notes: \*\* significative at 95% and \* significative at 68%. "Target" corresponds to a conventional monetary policy shock; "Forward guidance" to a surprise in forward guidance policy; "Public QE" to a shock to public securities purchase programs; and "Private QE" to a shock to private securities purchase programs.

We summarize the impulse responses of the SRISK indicator to conventional (target) and UMP shocks (forward guidance, public QE and private QE) for three different horizons (3 months, 12 months, 24 months after the initial shocks) in table 10.

Some heterogeneity across the countries is immediately visible if we compare the responses of the SRISK to the public QE and the private QE. First, the public QE surprise leads to a significant increase in the SRISK in Spain and France in the medium term (12 months after the shock) and in Italy and France in the longer run (24 months after the shock). This contrasts with the much more modest reaction of the German SRISK. It can be explained by a much better situation of

Germany regarding its public debt and therefore, the healthier balance sheets of German banks. We can also see that public QE had a stabilising effect in the short term in Italy, this decrease being certainly justified by the ECB's willingness to lower spreads in the countries where they were highest to reduce fragmentation problems in the transmission of monetary policy.

Regarding the private QE, we can observe that it leads to a significant rise in the SRISK in France and Italy 12 months after the initial shock. However, in the longer term, the response of the SRISK indicator is negative for the four European countries (with the strongest effect for Italy and Spain), reflecting a stabilising effect of this measure. It can be linked to the reduction of credit risk as a result of the positive real economic outcomes of the CSPP.

## 5 Conclusion

In this paper, we study the reaction of two financial stability indicators to four monetary policy shocks: conventional monetary policy, forward guidance, private quantitative easing and public quantitative easing. This question is central to the current monetary and macroprudential policy debate around the world. Undesirable effects on financial stability and market distortions, caused by UMP tools, are regularly mentioned as key issues to be monitored. The main innovation of our research is to propose a strategy to disentangle private asset purchase programs from public ones, by adding the identifying assumptions that these two programs have the opposite effect on the corporate bond spread. Our four factors seem robust as they have the expected effect on the yield curve and correspond to notable Fed and ECB monetary policy announcements. While our findings show that there is evidence for financial stability side effects of unconventional monetary policy instruments, these effects remain temporary and therefore do not pose a threat to financial stability.



# CHAPTER 3

## Announcement effects of Federal Reserve Quantitative Tightening on Financial Markets<sup>51</sup>

*« I would just stress how uncertain the effect is of shrinking the balance sheet. », Jerome Powell  
(May 4, 2022)*

### 1 Introduction

In 2022, central banks began tightening their monetary policy to counter inflation running well above their long-run target. The Federal Reserve (Fed), the European Central Bank (ECB) and the Bank of England (BoE) have respectively increased their interest rates by 475, 350 and 400 basis points, as of April 2023. Central banks have also begun to normalise their balance sheet, that reached record level with assets purchased in response to the global financial crisis and more recently to the COVID-19 Pandemic. The BoE started the unwinding of corporate bonds in September 2022 and the reduction in the stock of gilts comprising both maturing and sales in November 2022. The ECB started the reduction of its balance sheet in March 2023 by not reinvesting around EUR 15 billions of its Asset Purchase Programme (APP) maturing assets on a monthly basis. Other central

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<sup>51</sup>This chapter is under review in Economic Letters.

banks around the world have also started to implement Quantitative Tightening (QT): the Bank of Canada, the Reserve Bank of Australia, Sweden's Riksbank with passive QT, and the Reserve Bank of New Zealand with active QT<sup>52</sup>. Regarding the Fed, its SOMA portfolio of securities increased from 0.5 trillion in November 2008 to over 9 trillion of dollars by the beginning of 2022 (see Figures 44 and 45 in the Appendix C.1). It published its principles for reducing its balance sheet<sup>53</sup> in January 2022, followed by a more detailed "plan"<sup>54</sup> in May 2022. QT started the following month when the Fed allowed some securities to mature without reinvestment up to monthly redemption caps. The Fed stopped reinvesting up to 30 billion of dollars in maturing Treasuries and 17.5 billion of dollars in maturing Mortgage-Backed-Securities<sup>55</sup> (MBS) every month, passively shrinking its assets. Those caps were risen to USD 60 billion and USD 35 billion as of September 2022. In practice, the Fed's holdings of Treasuries and MBS dropped by about USD 500 billion since quantitative tightening started in June 2022 (and as of April 2023), averaging USD 50 billion a month (See Table 18 in the Appendix C.1 for details of balance sheet components evolution). The Fed's balance sheet has not shrunk by the monthly target of USD 95 billion mostly because of the slow ramp-up of asset sales, and a lack of maturing MBS. Regarding the QT calendar, Fed Chairman Jerome Powell said in July 2022 that the Fed's model suggested QT could run for two to two and a half years before bank reserves got down to a "new equilibrium" level after they surged during pandemic-era Fed easing<sup>56</sup>.

While quantitative tightening is currently overshadowed by policy rate hikes, it could have some impact on the financial market and its stability, at the time of its announcements and as it is implemented. The knowledge of the effects of unwinding central banks' balance sheet is essential for informed decisions by central bankers. An uncontrolled unwinding of the balance sheet could

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<sup>52</sup>The differences between the two types of QT will be explained in details in section 2.

<sup>53</sup>Principles for Reducing the Size of the Federal Reserve's Balance Sheet, January 26, 2022  
<https://www.federalreserve.gov/newsevents/pressreleases/monetary20220126c.htm>

<sup>54</sup>Minutes of the Federal Open Market Committee (May 3-4, 2022)  
<https://www.federalreserve.gov/newsevents/pressreleases/monetary20220525a.htm>

<sup>55</sup>MBSs are fixed-income securities backed by a pool of mortgages that represent claims on the principal and interest payments of the underlying loans.

<sup>56</sup>FOMC Press Conference, July 27, 2022

destabilize financial markets and lead to liquidity market stress episodes. We learned in 2019<sup>57</sup> that the Fed needs to maintain a flexible approach to its balance sheet policy. More recently, the collapse of Silicon Valley Bank (SVB) in March 2023, partly due to significant losses on long-term Treasuries, showed the possible harmful effects of very strong monetary tightening combining monetary policy rate hikes and QT. Despite its importance, there is a lack of literature of the financial markets' impact of reducing the central bank's balance sheet. The uncertainty regarding the effects of QT was stressed by Jerome Powell at the Press Conference on May 4, 2022: « *I would just stress how uncertain the effect is of shrinking the balance sheet* » and by Isabel Schnabel at her speech on March 2, 2023: « *How quantitative tightening operates in practice, however, is highly uncertain* ». The Fed's quantitative tightening from 2017 to 2019 is the only other experience of QT, leaving little empirical evidence to draw to study its effects. Furthermore, we can't deduce the effects of QT from the effects of Quantitative Easing (QE), which have been strongly demonstrated in the literature (Joyce, Lasao, et al. 2010). The main reason is that some transmission channels active during QE could be absent or attenuated during QT and QT may have its own transmission channels. Smith and Valcarcel (2023) demonstrate this asymmetry during the United-States 2017-19 QT experience. They showed that (i) QT tightened financial conditions, but its effects were not equivalent to those of QE in reverse and (ii) the signalling effect of QE, which played an important role when assets purchases were made, were mostly absent from QT announcements. On the financial stability side, QE and QT seem to have their own channels. QE can threaten financial stability through the risk-taking channel. QT could destabilize markets through (i) the withdrawal of bank reserves, (ii) the weakening of demand for Treasuries and Mortgage-backed-Securities (liquidity risk) and (iii) the loss of market value of sovereign bonds and other securities.

In this paper, we study the announcements effects of unwinding Fed balance sheet on (i) a wide range of financial assets prices (fixed-income, equities, forex and commodities) and (ii) financial stability metrics (volatility and liquidity indicators). We compare these effects with the announcements' impact of QE and tapering. The latter is the process of reducing the pace of assets purchases,

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<sup>57</sup>Mid-September tensions in the US dollar market for repurchase agreements (Repos)

but the balance sheet is still being expanded, though at a slower rate. We limit our analysis to the announcements effects of QT, i.e. very short-term market reactions, to take into account the decisions taken by the Fed in 2022 relative to the normalisation of its balance sheet. Not enough time has elapsed since the deployment of those measures to study their implementation effects in the medium and long term.

Our first innovation is to compare the reaction of our financial variables to quantitative easing, tapering and quantitative tightening announcements and highlight the asymmetries between these three instruments. Our second contribution is to study the reaction of all asset classes (i.e. fixed-income, equities, forex, commodities) and financial stability metrics to central bank's balance sheet communication. The objective is to have an overall vision of financial markets' reactions to QT announcements. Do these three types of balance sheet policies induce price readjustments at the time of their announcement? If so, do the price changes involve only the assets concerned by the announcement (treasuries and MBS) or do these changes extend to all asset classes? The literature often limits to the response of treasuries and corporate bond yields to monetary policy announcements. However, when we study the short-term reaction of financial markets to policy announcements, all asset prices may be subject to significant movements. Is the communication around them destabilizing and stressing investors? Or, on the contrary, have investors already readjusted their prices beforehand?

We build on the methodology of Cahill et al. (2013), who rely on relative price changes of financial assets in small time windows around QT announcements. But, differently from that study, we add two control variables in our regressions. Indeed, in a window of two days around the announcements, some other news may affect financial assets' prices. Thus, we add a daily index of United-States' economic surprises and the variation of the Fed Fund Futures<sup>58</sup>.

Our findings show strong asymmetries in the reaction of financial markets to balance sheet expansions, normalisation and unwinds. QE and Tapering events lead to strong variations in the

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<sup>58</sup>Financial futures contracts based on the federal funds rate and traded on the Chicago Mercantile Exchange (CME)

price of all asset classes, while QT announcements had been fully anticipated by the market players. These differences are the result of the way the Fed communicates its monetary policy decisions. Thus, during the QE announcements, the Fed handled its communication in such a way as to surprise the markets and cause price variations. On the other hand, the Fed wants to conduct its QT policy without destabilizing the financial market. It does this by being fully transparent in its communication about its asset purchase reductions and by notifying market participants well in advance so that they can integrate this into assets' prices before the announcement. The tapering announcements are a special case, in that the strong market reaction was not anticipated by the Fed. This has led the Fed to review the way it communicates this kind of policy. These asymmetries in reactions to monetary policy announcements demonstrate the power of central bank communication in affecting market expectations. Our second main result is that none of these measures lead to financial instability at the time of their announcements, except QT which affects the liquidity of the Treasury market. This finding is consistent with the fact that QT drains liquidity from markets by removing a guaranteed buyer of massive amounts of debt securities. Thus, while central bank communication around QT is effective in avoiding market disruption, it is not enough to eliminate stress around Treasury market liquidity.

The remainder of the paper proceeds as follows. Section 2 explains in details the concept of quantitative tightening and the literature relative to its impact of financial market. Section 3 describes our event-study methodology and presents our main results. Finally, Section 4 concludes.

## **2 Quantitative tightening and financial markets**

### **2.1 Zoom on the concept of Quantitative Tightening**

Quantitative tightening refers to the reduction of the surplus of liquidity in the central bank's balance sheet resulting from large scale assets purchases programmes. This measure can be used for different objectives: (i) to reduce the level of monetary policy accommodation, (ii) to regain policy space when excess liquidity is higher than needed, (iii) to mitigate negative side effects of a

larger balance sheet (Isabel Schnabel March 2, 2023<sup>59</sup>). There are two ways to reduce the size of central banks' balance sheet through quantitative tightening. The most intuitive way is to sell the securities bought during quantitative easing (active QT). The second is to not (or not fully) reinvest the proceeds of maturing bonds and let the balance sheet decline mechanically (passive QT). In the latter case, the pace of decline in securities holdings depends on the maturity structure of the securities portfolio and on the extent of partial reinvestment. The Fed used this second option during its 2017-2019 QT and is proceeding in the same way today, although it has not totally ruled out the sale of MBS. When a bond matures, the central bank recovers the redemption value and destroys the corresponding currency on the asset side of its balance sheet. In accordance with the double-entry principle in accounting, this action must also be reflected on the liabilities side. This is done by reducing by the same amount the reserves of commercial banks. Thus, quantitative tightening reduces the central bank's balance sheet and the reserve level of commercial banks and changes the composition of the balance sheet of private investors.

As described in the figure below, the cash the Fed receives as proceeds from the Treasuries (*-100 Treasuries repaid*) cancel out some of the cash reserves that the Fed owes to commercial banks (*-100 Reserves*). The QE transaction is thus reversed. This reduces the assets and liabilities sides of its balance sheet by equal amounts, and the assets side of commercial banks (*-100 Reserves*). When the U.S. Treasury issues new Treasuries, investors replace the Fed as buyer (*+100 UST due investor*). Indeed, without the central bank purchasing government bonds, the ongoing funding needs of government must be met with additional purchases from the public. The majority of Treasuries will be purchased by a non-bank investor. The later will swap their bank deposits (*-100 Deposits*) for Treasuries (*+100 Treasuries*), reducing commercial bank deposits (liabilities) and reserves (assets) just as QE created them. For the U.S. Treasury, nothing changes in its balance sheet, except of the ownership of Treasuries issued. Hence, will increase the amount of Treasuries in the hands of private investors.

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<sup>59</sup>"Quantitative tightening: rationale and market impact", Speech by Isabel Schnabel, at the Money Market Contact Group meeting, Frankfurt am Main, 2 March 2023

Figure 26: Balance sheet movements of the different actors impacted by QT policy

Assets	Liabilities	Assets	Liabilities
+ 100 Reserves	+100 UST due investor	-100 Treasuries repaid	-100 Reserves
- 100 Reserves to Fed	-100 UST repaid to Fed		

(a) Treasury: issued new treasuries

(b) Fed: receives payment and drops it

Assets	Liabilities	Assets	Liabilities
-100 Reserves	-100 Deposits	-100 Deposits	
		+100 Treasuries	

(c) Commercial bank: settles payment

(d) Investor: buys treasuries

Notes: (i) Fed: the UST (U.S. Treasuries) is repaid with the repayment extinguishing the Reserves liabilities created to purchase the Treasury in the first place. (ii) Treasury: only the ownership of Treasuries issued changed (investor instead of the Fed). (iii) Banks: QT shrinks the balance sheet of banks by reducing their reserve assets and deposit liabilities. (iv) Investor: he swaps one form of money (bank deposits) for another (U.S. Treasuries).

To ensure a gradual depletion of the balance sheet, the Fed sets caps on the monthly amounts of maturing securities allowed not to be replaced. Thus, the Fed used the partial reinvestment of maturing assets rather than the fully passive QT. The Fed will reinvest any maturing amounts above the monthly caps by reinvesting at auctions for Treasury securities or by purchasing securities in the secondary market in the case of agency MBS. For example, if the Fed receives USD 40 billion in redemptions of its maturing securities but limits the pace of quantitative tightening to USD 20 billion per month, it will reinvest only the USD 20 billion difference. It is also possible that the repayments will be well below the caps. The Fed's current monthly caps are USD 60 billion for Treasuries and USD 35 billion for MBS. Thus, the Fed's balance sheet is shrinking by a maximum of USD 95 billion per month.

If the Fed's SOMA Treasury holdings have a known runoff path since Treasury security maturities follow a defined schedule, it is more complex for MBS. Indeed, mortgages pay principal each month and these principal payments are not known in advance. Mortgage borrowers have the option to prepay their mortgages, for example to refinance an existing mortgage at a lower rate or to pay off a mortgage to move to a new home. With the 30-year mortgage rate having doubled in recent months (above 7% in February 2023), the majority of MBS securities on the Fed's balance

sheet will not mature for a long time. This is because homeowners have little incentive to refinance their mortgages now, and may be more reluctant to move. This means that investors (the Fed) are seeing their principal payments come in more slowly than in past years and that monthly principal payments would likely not exceed the Fed monthly cap. Thus, selling MBS could be a solution to reduce the amount of MBS on the Fed's balance sheet. Moreover, the central bank wants to eventually hold only government bonds on its balance sheet.

To sum up, the evolution of the Fed's balance sheet going forward will depend on several parameters: (i) the composition of the Fed's portfolio when the roll-off starts, (ii) the level of U.S. Treasuries and MBS paydowns that can be anticipated forward, (iii) the Fed's decisions to reinvest paydowns using a schedule of roll-off caps, (iv) the asset composition of any reinvestments the Fed decides to make and (v) the Fed's decisions on selling some portfolio assets if paydowns are low.

## **2.2 Quantitative Tightening's impact on financial markets and its stability**

While the effects of quantitative easing have been extensively studied and demonstrated (Krishnamurthy and Vissing-Jorgensen 2011; Joyce, Lasao, et al. 2010; Koijen et al. 2021), the effects of quantitative tightening are still very much in doubt. As stated above, there has been only one experiment in quantitative tightening so far, and that lasted only two years. QT can impact market (i) at the time of central bankers' announcements (announcements and signalling effects) and (ii) as the measure is deployed (liquidity and portfolio channels). The potential impact of QT on market rates and prices can lead to financial instability through (i) liquidity market stress on money market and bond market and (ii) significant valuations loss for bond holders.

First, quantitative tightening may put upward pressures on medium and long-term yields, causing the yield curve to steepen, mostly through the portfolio rebalancing channel (Krishnamurthy and Vissing-Jorgensen 2011; Breckenfelder et al. 2016). QT may affect different components of the term



premium<sup>60</sup> on medium and long term yields, by modifying the average maturity and the duration<sup>61</sup> risk of private portfolios (Thornton 2012). When Treasury securities or MBS reach their maturity date, new securities will be issued. However, as the Federal Reserve is running off its balance sheet, it will not reinvest the proceeds from maturing assets or at least not the full amount. Other investors, both in the United-States and abroad, will have to increase their portfolio exposition to treasuries and/or MBS. With a significant increase in supply hitting the market in coming years and the largest uneconomic buyer exiting stage left, pressure should build for yields to move higher. There is an additional risk facing the market for corporate bonds. While their yields would most likely move higher in sympathy with those of government debt, corporate securities are also vulnerable to a re-widening of credit spreads that have been crushed as a result of the global reach for yield. As interest rates and bond prices move in opposite directions, higher bonds yields will cut the value of bonds on the balance sheets of the holders of these assets. Such losses can threaten financial stability in certain circumstances. For example, big losses on long-maturity treasuries were partly responsible for the collapse of Silicon Valley Bank (SVB) in March 2023.<sup>62</sup> An other threat to financial stability can emerge from a lack of demand on the Treasury market. If Treasury market are characterized by poor market liquidity and fragmented market structure, the end of Fed's purchases can lead to heightened volatility in treasuries and therefore threaten financial stability. As demonstrated in the United-Kingdom in September and October 2022, volatility in a country's sovereign debt can rapidly lead to unpredictable consequences.<sup>63</sup> In the case of the eurozone, a third risk adds up: financial fragmentation of sovereign bond markets with widening spreads of some countries versus German yields (Alberola-Ila et al. 2022).

The normalisation of the balance sheet, by reducing the supply of reserve balances, can also put upward pressures on short-term money market rates through market liquidity effects. This effect

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<sup>60</sup>Extra return (a risk premium) that investors demand to compensate them for the risk associated with a long-term bond (BIS Quaterly Review, 23 September 2018).

<sup>61</sup>Measure of the sensitivity of a bond's or fixed income portfolio's price to changes in interest rates.

<sup>62</sup>SVB looked to sell USD 2 billion of its investments (essentially treasuries) at a loss to help boost liquidity for its struggling balance sheet. Depositors withdrew funds in droves, spurring a liquidity squeeze and prompting California regulators and the FDIC to step in and shut down the bank.

<sup>63</sup>Fire-sale in Gilts leading to sharp rise in yields, set off by (i) the announced change in the UK fiscal stance and (ii) amplified by forced selling due to rapid deleveraging by investment vehicles used by pension funds.

is not linear, and can occur as soon as the total quantity of reserves in circulation approaches the minimum level that banks need. This type of stress can even lead to a liquidity crisis when banks' reserve needs are not met, causing interest rates on the interbank market to rise. These effects can be exacerbated by self-fulfilling expectations. For example, the 2017-2019 QT program of the Fed ended abruptly after the Repo<sup>64</sup> blowup in September 2019. Bank reserves dropped below the minimum level needed to ensure smooth functioning of funding markets, leading to large spikes in the Secured Overnight Financing Rate (SOFR)<sup>65</sup>. In an efficient wholesale funding market, SOFR would be essentially equated by arbitrage with the overnight interest rate offered by the Fed on balances held at the Fed (IOR), because they are nearly equivalent risk-free overnight investments available to banks (Copeland, Duffie, and Yang 2021). Acharya, Chauhan, et al. (2022) observe an asymmetric behavior of banks during QE and QT. During QE, banking deposits increase and become more in demand, banks originates more corporate lines of credit, and during QT, there are little reversal of all this. Indeed, they argue that this makes the banking system dependent on the central bank for ever larger liquidity infusions during stress and can explain tightening liquidity conditions and occasional stress episodes when quantitative tightening is underway. Bräuning (2017) estimated a significant increase in the effective federal funds spread and the overnight repurchase agreement (repo) spread (relative to the lower bound of the federal funds target range) as a response to a drain in reserves. He also found a nonlinear liquidity effect depending on the total supply of reserves. Smith and Valcarcel (2023) found that the liquidity effects were roughly double those experienced under QE. As the Fed allows maturing securities to fall off the asset side of its balance sheet, it shrinks reserves on the liability side by an equivalent amount. Evidence for the United States suggests that QE made bank liabilities increase and become of shorter maturity, which 2017-19 QT did not reverse to a commensurate extent. Banks could thus become more sensitive to liquidity shocks now that QT is again underway (Acharya, Chauhan, et al. 2022).

To sum up, the two main risks of QT for financial stability are (i) the scarcity of reserves and

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<sup>64</sup>Repos are a common secured money market transaction. The Desk purchases securities from a counterparty subject to an agreement to resell the securities at a later date.

<sup>65</sup>A broad measure of overnight Treasury repo rates.

loss of control over money market rates and (ii) large swings in bond's prices and possible ripple effects. These risks may arise as the measure is deployed but also at the time of QT announcement, if the anticipation of these effects lead to panic behaviour from market players. One of the transmission channels that has been demonstrated in particular in the context of QE is the signalling channel. QE affects bond yields through new information provided to investors about the future path of short-term interest rates which changes the risk-neutral component of interest rates. By (i) changing its view on current or future economic conditions or (ii) changing its monetary policy reaction function, QE announcements lower the expectations component of long-term yields. On the contrary, the reduction in the balance sheet could send the signal of a future monetary tightening and therefore the upward readjustment of expectations of the key rate. Such a signaling channel for QT would increase yields by raising the average expected short-rate (or risk-neutral) component of long-term rates. This signalling effect is less important when policy can be tightened by raising interest rates and QT takes place in a gradual and predictable way (Bullard, 2019 ; Lane, 2022). According to Smith and Valcarcel (2023), signalling effects was mostly absent from the first episode of QT announcements (2017-2019), a huge contrast with QE events that typically contain a large signalling component (Bauer and Rudebusch 2014; Krishnamurthy and Vissing-Jorgensen 2011). While the Fed is moving more quickly with QT in 2022, it still took steps to ensure there were no market surprises. Announcements effects strongly depend on the interpretations of financial market players of the communication of central bankers ("hawkish" or "dovish" tone<sup>66</sup>). A restrictive monetary policy announcement can be interpreted as "dovish" by market participants if they were expecting a more severe tightening. Thus, the initial announcement could have the opposite effect of what was intended. These announcements effects can impact all asset classes. For example, the real vulnerability following QT announcements in a context of slowing growth will be in riskier asset classes (equities or real estate) due to mounting fears about the growth outlook. Indeed, by rising rates, QT could amplify the economic downturn, which could negatively affect corporate earnings and de facto negatively impact equities performance.

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<sup>66</sup>Hawkish refers to policy makers who favor higher interest rates to keep inflation in check. Dovish refers to policy makers who prefers an interest rate policy that is more accommodative to stimulate spending in an economy.

## 2.3 Data Analysis

In this section, we have a first look on the reaction of asset prices around balance sheet's announcements through a description analysis. We observe the average two-days variation of some asset prices around all the events<sup>67</sup> of (i) quantitative tightening in pink ; (ii) tapering in blue ; (iii) quantitative easing in grey. In the first figure, we see the reaction of the different variables rates (in basis points) and in the second figure, those of the price variables (in %). Long-term treasuries yields, corporate bond yields and MBS yields drop around QE announcements, rise around Tapering events and remain stable around QT announcements. The average yields variations around QE and tapering events are perfectly symmetrical: in average, MBS yields increase by 21 basis points in a two-days window around QE announcements and drop by 23 basis points after tapering announcements. Such reactions assume a priori that these announcements were not reflected in the market prices, and therefore that the market players were surprised by these events. In contrast, QT announcements appear to have almost no effect on market variables, meaning that market participants were fully prepared for the announcement of these measures. We find this symmetry in QE and Tapering announcements for the bond global aggregate total return, the dollar index and gold price. The variations around QT events are in the same direction as those around the Tapering but are much less. On average, the three events seem to generate a negative performance of the S&P 500 and a decrease in the price of oil and in the High Yield spread. The relationship between these policy measures and these variables is less direct and depends on the level of stress in financial markets. We also do this exercise in a 3-days window around Fed announcements to observe the sensitivity of our variables to window size. If we look at figure 46 in the Appendix C.5, we can see that the window size causes very little variation in the variables around the announcement.

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<sup>67</sup>See details in the tables 19, 20 and 21 of the Appendix C.2.

Figure 27: Financial market impact of QE, Taper and QT

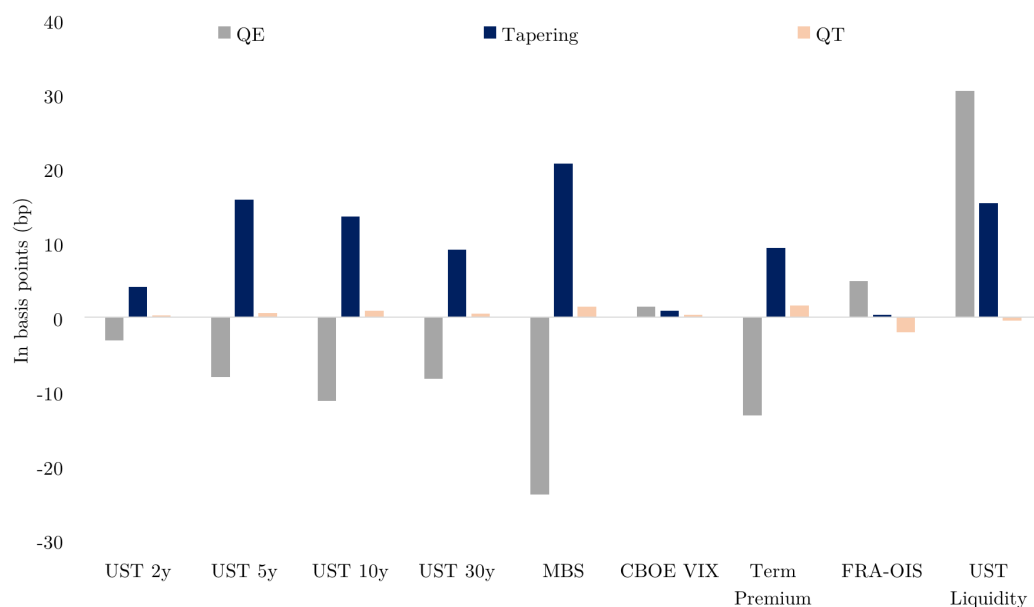
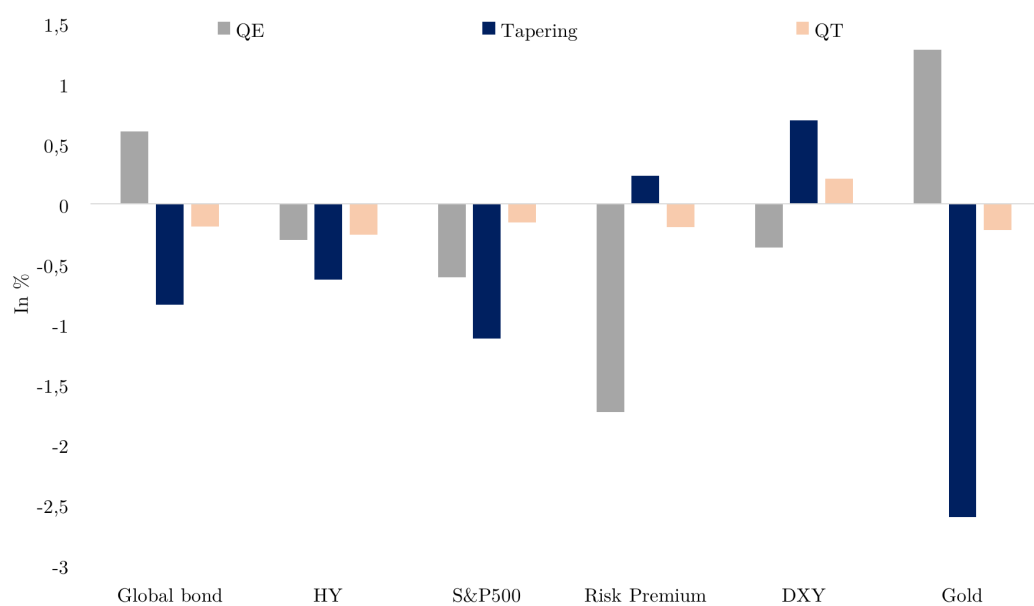


Figure 28: Financial market impact of QE, Taper and QT



Notes: Average two-days variation of asset prices (closing price) around all QT events (in pink), all tapering events (in blue) and all QE events (in grey).

Variables : Treasuries yields (30y, 10y, 5y, 2y), Moody's BAA corporate bond yield (investment grade bonds), MBS yield, Bloomberg Global-Aggregate Total Return Index, ICE BofA US High Yield Index Option-Adjusted Spread, 3-Month Eurodollar CME, S&P 500 index, gold Spot/Oz, Brent Crude Oil price.

### 3 Were there announcement effects during QT?

#### 3.1 Event-Study Methodology

In this section, we use the event study methodology to detect announcement effects on financial markets stemming from balance sheet unwind. We compare the effects of quantitative tightening to those of (i) tapering and (ii) quantitative easing. In particular, we examine changes in asset prices around official communications regarding these three balance sheet instruments, taking the cumulative changes as a measure of the overall effects.

Our event study follows a large literature that measures the financial market effects of monetary policy by studying the responses of asset prices in small windows around Federal Reserve announcements (Gagnon, Raskin, Remache, and B. Sack 2011; Krishnamurthy and Vissing-Jorgensen 2011; Swanson 2021; Smith and Valcarcel 2023). The event study methodology is premised on the assumption that markets are efficient and forward-looking, meaning that the prices of financial assets reflect all available information, both past and present, as well as expectations about the future (Fama 1969). Thus, expectations of monetary policy are reflected in asset prices before any announcement. Therefore, the variation in asset prices following the monetary policy announcements primarily reflects the revision of policy expectations by market players, i.e. the surprise component of monetary policy announcement. If the market participants had perfectly anticipated the monetary policy announcement, asset prices will not move following the announcement. On the other hand, if the central banker announces, for example, a higher-than-expected rate hike, asset prices will react to the announcement because expectations will be readjusted and thus incorporated into prices.

##### 3.1.1 QE, QT and tapering events & data

To perform an event-study analysis of Fed’s balance sheet measures, one must first identify major announcements that carried significant news about these programmes. We focus on a narrow set of official communications (FOMC meetings, Fed testimonies, Fed chairman’s speeches, press

conference reports and Fed minutes released), each of which contained new information concerning the potential or actual expansion or diminution of the size, composition, and timing of these measures<sup>68</sup>. A total of 18 communication events for QE, 3 for tapering and 12 for quantitative tightening are identified and reported in tables 19, 20 and 21 in the Appendix C.2. Regarding QT announcements, 10 are related to the Fed QT (between 2017 and 2019) and two are related to the second Fed QT (the publication of the minutes on April 6, 2022 and the announcement of the beginning of the QT on May 4, 2022).

Once the announcements identified, we built our dataset by capturing the average reaction of yield variables and price variables to all announcements related to (i) QE, (ii) Tapering and (iii) QT between 2008 November and 2022 May.

We study the announcement effects of QT, Tapering and QE on (i) a wide range of asset classes and on (ii) market financial stability metrics. The objective is to have an overview of all the possible effects stated in the section 2.2 and to show the differences in the market reaction to these three types of balance sheet policies. More specifically, we focus on the following variables (see table 22 in the Appendix C.3 for more details) :

- **Bond market** with *U.S. Treasury yields from different maturities (2-, 5-, 10-, 30 year)*, *Bloomberg US Mortgage-Backed-Securities index average yield-to-worst*, *10 year Treasury term premium*, *Bloomberg Global aggregate total return index* and *global high yield total return index*. The idea is to look at the effect of QT, QE and tapering on the most impacted asset classes by these balance sheet measures (treasuries and MBS) and the impact on the other bond classes (i.e High Yield corporate bonds for example).
- **Stock market** with *S&P 500*, *S&P 500 Banks* (to take into account the potentially greater impact on banks, more affected by rates changes), *S&P 500 Equity risk premium total return index*. Equity markets can be impacted by QT through its effects on bond yields. Rising interest rates (i) may cause investors to switch from equities to bonds, which now offer a

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<sup>68</sup>Sources: Smith & Valcarcel, 2021 ; FOMC Meeting Meeting calendars, statements, and minutes ; Federal Reserve History of the FOMC's Policy Normalization Discussions and Communications.

better return than before and (ii) may amplify the economic downturn, which could negatively affect corporate earnings and de facto negatively impact equities performance.

- **Other asset classes** with *dollar index*, *gold price spot in USD (by ounce)*, *Brent Crude Oil Continuous Contract (USD/bbl)*. The first two variables are directly affected by rate variations.
- **Market stability metrics** with *CBOE VIX* (volatility indicator of the U.S. equity market), *MOVE index* (volatility indicator of the U.S. Treasury market), *FRA-OIS Spread* (funding market liquidity indicator), *U.S. Gov. securities liquidity index*, *10y UST Bid-Ask spread* (U.S. Treasury liquidity indicators), *OFR FSI index* (global financial market stress indicator). The objective is to evaluate if these three monetary measures create stress on the markets at the time of their announcements. We have selected global stress indicators as well as stress indicators for the Treasury market, the main market affected by these instruments.

### 3.1.2 Event Window & Model

We follow Krishnamurthy and Vissing-Jorgensen (2011) and Smith and Valcarcel (2023) and study the change in bond yields and other asset prices in a two-day window around Fed announcements, measured from the closing level the day prior to the announcement to the closing level the day after the announcement. The two-day window allows for late-in-the-day announcements effects to fully reflect through to asset prices the following day. However, we risk the estimated reaction being contaminated by other news events. To prevent this, we add two control variables to our model: (i) the *CME 30 days Fed fund futures* and (ii) the *Bloomberg economic surprises*<sup>69</sup> to neutralize changes in asset prices due to (i) announcements related to changes in Fed fund rates (conventional monetary policy) and (ii) United-States macroeconomic publications.

Fed fund futures are financial contracts that allow market participants to speculate on the future level of the Federal Reserve’s target for the federal funds rate. They are frequently used to calculate market-based monetary policy surprises (K. N. Kuttner 2001; Gürkaynak, B. Sack, and E.

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<sup>69</sup>See the table 22 of the Appendix C.3 for more details



Swanson 2005). The addition of this variable is particularly necessary. Without this variable, the differences in effects between QE and QT could be entirely explained by conventional monetary policy. Indeed, QE is implemented when running off conventional tools while QT is conducted in parallel to interest rate hikes. Moreover, market reactions during QT events may actually be solely due to Fed rate changes. The Fed's objective is to set QT on a fixed course and not have it be the focus of investors' attention, because they want investors paying attention to the federal funds rate as the instrument of monetary policy.

Bloomberg economic surprises are indices that measure the extent to which the actual outcomes of economic indicators (such as GDP growth, manufacturing PMI, employment figures, etc.) differ from the consensus expectations of analysts.

For robustness, we also examine the impact of using three-days windows around the announcement (see tables 23, 24 and 25 in the Appendix C.4). We can observe that the announcements impact is similar when we use a 2-days window and a 3-days window around QT, QE and tapering announcements. Using a much shorter (intraday) window would not capture the overall effect of the communication (see M. A. S. Joyce et al. (2011)).

We run OLS regressions for each financial markets variables:

$$\Delta Y_t = \beta^{QE} QE_t + \beta^{Taper} Taper_t + \beta^{QT} QT_t + \alpha_1 X_1 + \alpha_2 \Delta X_2 + \epsilon_t \quad (15)$$

Where  $\Delta Y_t$  is the two-day change in the yield or percent change in asset price and  $QE_t$ ,  $Taper_t$  and  $QT_t$  are dummy variables, which takes a value 1 on the dates that were related quantitative easing, tapering or quantitative tightening events.  $X_1$  and  $X_2$ , the control variables correspond respectively to economic surprises and Fed fund futures. As in Cahill et al. (2013),  $X_1$  is not in first difference, as the data already is a the difference between actual and expected data prints or unanticipated events.

### 3.2 Results

Table 11: Change over 2 days around the announcement (in basis points)

	<b>UST 2y</b>	<b>UST 5y</b>	<b>UST 10y</b>	<b>UST 30y</b>	<b>MBS</b>
All QE Events	-3.03*	-7.88***	-11.05***	-8.07***	-23.67***
	(1.35)	(1.81)	(1.83)	(1.82)	(2.69)
All Taper Events	3.93	15.72***	13.45**	9.09**	20.61***
	(3.30)	(4.42)	(4.48)	(4.44)	(6.57)
All QT Events	-0.50	-0.07	0.45	0.17	1.07
	(1.65)	(2.21)	(2.24)	(2.22)	(3.29)
Fed Fund Futures	-34.41***	-28.79***	-20.79***	-16.08***	-15.21***
	(2.16)	(2.89)	(2.93)	(2.90)	(4.32)

	<b>Term premium</b>	<b>CBOE VIX</b>	<b>FRA-OIS</b>	<b>UST Liquidity</b>
All QE Events	-12.92***	1.48*	4.96	30.77
	(4.26)	(0.62)	(3.67)	(20.33)
All Taper Events	9.35	0.87	0.40	15.67
	(10.40)	(1.51)	(8.96)	(49.64)
All QT Events	1.64	0.43	-1.70	-0.10
	(5.21)	(0.75)	(4.48)	(24.86)
Fed Fund Futures	0.95	5.11***	12.63**	2.57
	(6.80)	(0.99)	(5.86)	(32.45)

Table 12: Change over 2 days around the announcement (in %)

	<b>Global Bond</b>	<b>HY</b>	<b>S&amp;P500</b>	<b>S&amp;P500 Banks</b>	<b>Risk prem.</b>
All QE Events	0.58***	-0.29**	-0.65*	-0.62*	-1.70***
	(0.10)	(0.14)	(0.39)	(0.13)	(0.63)
All Taper Events	-0.63**	-0.63*	-1.20	-0.91	0.18
	(0.26)	(0.36)	(0.96)	(0.33)	(1.55)
All QT Events	-0.28	-0.28	-0.30	-0.10	-0.34
	(0.13)	(0.18)	(0.48)	(0.16)	(0.77)
Fed Fund Futures	1.28***	-1.14***	-3.21***	-3.22***	-5.41***
	(0.17)	(0.23)	(0.64)	(0.62)	(0.81)

	<b>DXY</b>	<b>Gold</b>	<b>Brent</b>	<b>UST Bid-Ask</b>	<b>FSI</b>	<b>MOVE</b>
All QE Events	-0.38* (0.16)	1.22*** (0.37)	-2.36 (2.62)	0.58 (10.02)	19.61 (20.01)	-5.35* (2.91)
All Taper Events	0.67* (0.39)	-2.64*** (0.91)	-1.25 (3.86)	-3.86 (24.46)	-13.70 (48.85)	11.53 (7.10)
All QT Events	0.16 (0.19)	-0.22 (0.45)	-0.84 (1.93)	28.66* (12.25)	-7.11 (24.46)	-0.29 (3.55)
Fed Fund Futures	-0.92 (0.25)	2.08*** (0.60)	-6.35** (2.53)	10.69 (15.99)	35.61* (19.22)	11.64** (4.65)

Notes: Coefficients  $\beta^{QE}$ ,  $\beta^{Taper}$  and  $\beta^{QT}$  from the regression:  $\Delta_{yt} = \beta^{QE} QE_t + \beta^{Taper} Taper_t + \beta^{QT} QT_t + \alpha_1 X_1 + \alpha_2 X_2 + \epsilon_t$ , where  $\Delta_{yt}$  is the two-day change in the yield or percent change in asset price and  $QE_t$ ,  $Taper_t$  and  $QT_t$  are dummy variables, which takes a value 1 on the dates that were related quantitative easing, tapering or quantitative tightening events.  $X_1$  and  $X_2$ , the control variables correspond respectively to economic surprises and Fed fund futures.

OLS standard errors are reported in parenthesis. Sample Period: November 2008 – May 2022. Observations: 3712. \*\*\* < 0.01, \*\* < 0.05, \* < 0.10.

The variables are not classified by asset class, but by unit. Table 14 groups variables expressed as percentages and therefore with variations in percentage points, while Table 15 groups indices, whose variations are expressed as percentages.

Table 11 shows the average two-days change in Treasuries 2-, 5-, 10-, 30-year yields, MBS yields (MBS), 10y Treasury term premium (Term premium), CBOE VIX, FRA-OIS spread, U.S. Treasury liquidity indicator (in basis points) over the 18 QE events, 3 tapering events and 12 QT events. The regression results for global bond total return index (global bond), high yield total return index (HY), S&P500, S&P500 banks, S&P500 risk premium (Risk prem.), dollar index (DXY), gold spot price, Brent, UST 10y bid-ask spread, FSI index and MOVE index are reported in table 12 (in %).

We can observe a huge heterogeneity in the reaction of yields to these three types of monetary announcements. As expected, QE announcements lead to the decrease of medium and long-term Treasury yields. Medium and long term bonds yields are made up of two parts: (i) the returns expected from comparable, shorter-dated instruments over the same time period, and (ii) the term premium. One of the transmission channel of QE is the term premium channel (Vaccaro-Grange 2019). Government bonds purchases by the central bank create a shortage of long-term safe bonds on the market, that leads to an increase in these bonds prices and a decrease in the term premium component of the associated yields. Then, market's participants re-balance the composition of their portfolio towards shorter-ones, or invest in maturity-equivalent corporate bonds (and other riskier assets). This mechanism appears here with a 13 basis points decrease in the term premium

following QE events. But this mechanism, in the opposite direction, seems absent from QT announcements. The strongest reaction to QE announcements is those of MBS yields, which drop on average by 24 basis points around QE events. The immediate reaction of yields to tapering events is perfectly symmetric. 10 year Treasury yields increase by 13 basis points, MBS yields by 20 basis points in average following tapering announcements. The effect on the term premium is positive but not statistically significant. However, QT announcements do not result in any change in bond yields.

The most striking result here is the difference in the reaction of yields to tapering and QT announcements. Intuitively, as QT policy is more restrictive than tapering, we could expect stronger market reactions to QT announcements. In fact, tapering announcements lead to meaningful upward revisions across much of the yield curve from market participants while these remain perfectly stable following QT communication. It means that tapering announcements have largely surprised the markets participants while they were perfectly prepared for QT. The lack of announcements effects from communication relative to balance sheet unwinding is compliant to the objective of the Federal Reserve. The Fed has taken great pains to avoid market surprises. It announced its plans for shrinking the balance sheet well in advance, and the QT process is happening passively following a fixed schedule. In 2017, Janet Yellen assured markets that QT would be like *"watching paint dry"*. This seems to be true, at least at the time of the program announcements.

Additionally, we observe no significant announcement effects of quantitative tightening on broader financial markets, in contrast to QE and taper events which affect financial variables not directly related to the content of the balance sheet of the Fed. This is consistent with previous results. In the context of monetary policy announcements, other asset classes mostly vary due to yields adjustments. Currency exchange rates move in response to rate differentials. Higher yields should, all else equal, lead to an appreciation of U.S. dollar according to the Uncovered Interest Rate Parity (UIRP) theory. Indeed, it states that the difference in interest rates between two countries will equal the relative change in currency foreign exchange rates over the same period. The average immediate reaction of dollar index to QE events is a depreciation of 0.38% which is consistent with

the decrease in U.S. yields. The dollar index increases on average by 0.67% following tapering events, in reaction of the 5-year yields increase of 15 basis points. It means that the content of tapering announcements had not been fully anticipated and that the surprise component of the announcement was a hawkish surprise for market participants. Thus, market participants revised their rate expectations upward, leading to higher U.S. yields and a stronger dollar. Regarding the reaction of gold price around these monetary announcements, it increases of 1.22% following QE events, decreases of 2.64% following tapering announcements and has no reaction following QT events. When bond yields decreases, investors may turn to gold as an alternative safe-haven asset to park their money. This increased demand for gold can push its price higher, while the low bond yields reduce the opportunity cost of holding a non-yielding asset like gold. This inverse relationship between real rates and gold price has been widely studied (Wang and Chueh 2013; Bhar and Hammoudeh 2011). Again, if the price of gold does not react to QT announcements, it means that market participants had already built into the price of gold the future rate increases to come due to the shrinking balance sheet. In contrast, during the tapering announcements, market players interpreted the central banker's words as a hawkish message. Tapering announcements exacted negative performance of the S&P500 of 1,20%. In contrast, announcements related specifically to unwinding past asset purchases caused no similar tightening (only -0,3%). Similar to higher interest rates, which can decrease corporate profitability and depress stock prices, QT can have an adverse effect on equities. When long-term bonds yields increase, investors may want to shift from stocks to long-term bonds. Indeed, if expected returns from bonds are higher, it reduces the need to own riskier assets (equities) to meet long-term investment goals for an investor. This effect does not materialize at the time of the announcement because the Fed had been transparent enough beforehand and investors have already readjusted their expectations in asset prices. Regarding the S&P 500 risk premium, it only reacts to QE events (-1.70%). As investors attempt to rebalance their portfolio away from Treasury bonds towards more risky assets (that offering more return), the additional compensation investors demand for the risk of holding U.S. equities (equity risk premium) fall. As investors are not surprised by QT announcements, and do not readjust bonds pricing, it is consistent that the risk premium is not affected either.

Tapering announcements came as a surprise to financial markets. In the immediate aftermath, bond investors started selling their bonds, causing prices to drop and yields to rise. Theoretically, rising yields can impact stock markets, too, as more attractive yields compete with stocks for investors' money. The U.S. stock markets saw some volatility in the weeks following Bernanke's testimony before the Congress. The CBOE VIX, often called the "fear gauge," measures expected volatility in the options markets, and it spiked in June 2013. The VIX's reaction to the tapering announcement was not significant, so this measure did not react directly to the announcement. Taking the taper announcement as a cue for tighter monetary policy, the U.S. dollar appreciated sharply. The turbulence created on financial markets was not intended by the Federal Reserve and it led it to reassess its communication of that unwinding process. In the context of the two QT episodes, central bankers made a point of being transparent and defining their policy well in advance of its application so as not to disrupt the markets. In June 14 2017, Federal Reserve Chair Yellen described the Federal Reserve's balance sheet normalization plan in the post-FOMC meeting press conference as follows :

*"We wanted to reduce our balance sheet **in a gradual and predictable way**" ; "so that when this plan does go into effect, **no one is taken by surprise** and market participants understand how this will work" ; "the plan is one that is consciously intended to **avoid creating market strains** and to allow the market to adjust to a **very gradual and predictable plan**" ; "something that will just **run quietly in the background** over a number of years"....*

- Yellen (2017)

We find this same objective in the words of Federal Reserve Chair Powell on May 4, 2022 :

*"The Committee intends to reduce the Federal Reserve's securities holdings over time **in a predictable manner**" ; "**consistent with the principles** we issued in January".*

- Powell (2022)

Regarding the effects of QE, tapering and QT announcements on financial stability metrics, two effects are significant and particularly interesting. First, QE announcements reduce the bond market volatility (MOVE index) by 5.35%, meaning the reduction of uncertainty about future changes in interest rates and the decrease of risk aversion. Secondly, QT events lead to an increase of 28% of the bid-ask spread of U.S. 10y Treasuries, i.e. an increase of the difference between the price that someone is willing to pay (the bid) and where someone is willing to sell (the offer or ask). Among all our variables, it is the only one that reacts to QT announcements. Wider bid-ask spreads occur in less liquid or highly-volatile markets. This spread widening following QT announcements suggests that bond investors are concerned by evaporating liquidity as the Fed winds down its Treasury holdings. This is consistent with the fact that QT drains liquidity from markets by removing a guaranteed buyer of massive amounts of debt securities. While QT has no effect on Treasury yields or asset prices at the time of its announcement, it does affect the liquidity in the Treasury market. The lack of effects of QT announcements on asset prices means that market participants have fully integrated this measure into their prices before it was announced. However, this does not prevent them from reducing their transactions on the Treasury market. These wider spreads reflect market players' stress over the Fed's gradual withdrawal as the market's main buyer. This is one of the main result of this chapter.

To conclude, all asset classes appeared to be unfazed by the Federal Reserve's communication around unwinding its balance sheet. While announcements related to tapering asset purchases led to a tightening in financial conditions, announcements related to shrinking the balance sheet and unwinding past purchases had no observable impact on financial markets. This disparity appears to be explained, at least in part, by differences in signaling effects. The lack of signaling effects, and more general announcement effects, from communication regarding unwinding the balance sheet appears to have been by design and was largely an objective of Federal Reserve officials. However, one of the fears surrounding QT is that it will dry up liquidity in the Treasury market. Despite asset price adjustments ahead of the announcements, liquidity in this market seems to be under stress following the announcements, as demonstrated by the bid-ask spread reaction.

### 3.3 A closer look at Quantitative Tightening and Tapering announcements

In this section, we proceed with a more detailed analysis of individual QT and tapering announcements. Indeed, our precedent analysis could mask some degree of heterogeneity across announcements effects. Moreover, this allows us to distinguish the effects of the first QT of the Fed (2017-2019) from those of the second QT, announced in May 2022 and initiated in June 2022. The second QT differs from the 2017-2019 QT on the following items: (i) larger caps (USD 95 billion a month versus maximum pace of USD 50 billion a month), (ii) faster ramp-up (from zero to USD 95 billion in the space of three months versus from zero to USD 50 billion in a full year), (iii) shorter treasuries' maturity portfolio (by about two years).

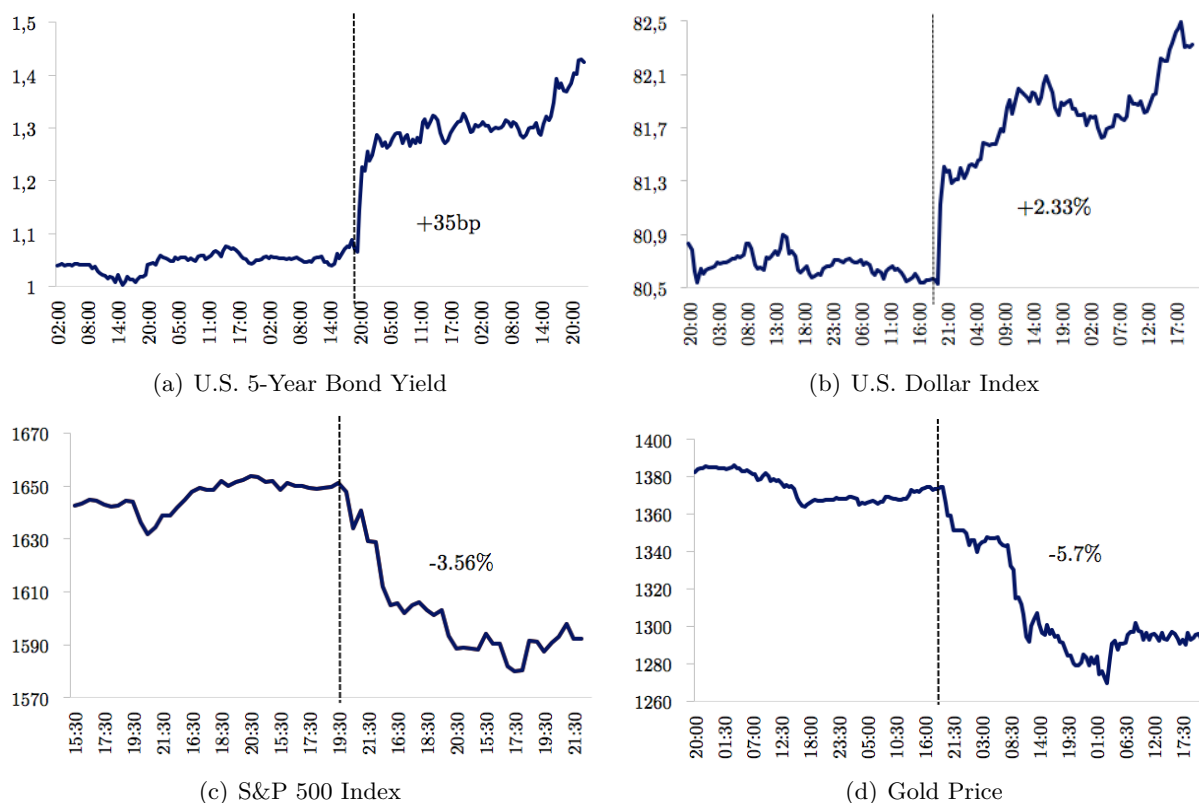
Table 13 shows the average two-days change in Treasuries 2-, 5-, 10-, 30-year, MBS yields, term premium, CBOE VIX, FRA-OIS spread, U.S. Treasury liquidity indicators (in basis points) over each of the 3 Taper events and the 12 QT events. The regression results for global bond index, HY price, S&P500, S&P500 banks, risk premium, dollar index, gold, Brent, UST 10y bid-ask spread, FSI and MOVE index are reported in table 14 (in %). If we focus on QT, the event-specific effects confirm the previous results. Investors seem to have perfectly anticipated the announcements of the central bankers, and these announcements do not generate any significant price variation and stress on the markets. However, the reaction of the bid-ask spread is no longer significant when focusing on specific events. Regarding tapering events, we can observe that the announcement of June 19, 2013 is responsible for almost all the effects discussed in the previous section.

Tapering announcement on June 19 2013 was the one that most disrupted the markets (see figure 29 below). Indeed, 5-, 10-, 30-year Treasury yields have respectively increased by 24, 23 and 17 basis points. MBS rose by 34 basis points. Regarding other assets, global bonds aggregate decreased by 2%, High Yield price by 1.4%. S&P 500 and NASDAQ respectively tumbled by 3.8%. Gold price plunged 6% and dollar index rose by 1.4%. These movements were all statistically significant. Ben Bernanke offered some of his most explicit guidance about when the central bank might start pulling back its stimulus. Depending on how the economy performs, Ben Bernanke said the Fed



could begin tapering its bond buying later this year and end the program some time in 2014. At the same time, he said the Fed could step up its stimulus efforts if the economy take a turn for the worse. Investors seemed surprised to hear Ben Bernanke spell it out in such detail and asset prices reacted as if the Fed was significantly reducing its stimulus plans. Markets misread the Fed's intentions and erroneously extrapolated the desire to "step down" purchases to mean that the Fed was making a bigger change in its accommodative stance. In the immediate aftermath of Ben Bernanke's comments, the market repriced its expectation for the future path of short-term interest rates (Fed fund futures) from one hike to four full hikes by mid-2015. Moreover, this Tapering announcements exacted higher volatility. Investors in all asset classes try to re-price what the world looks like in the absence of quantitative easing.

Figure 29: Change in asset prices around the tapering announcement of June 19, 2013.



Notes: The dotted line represents the moment when the FOMC Statement is published (2 p.m. Eastern). Intraday data from June 18 to June 21, 2013.

Regarding the two other Tapering announcements in May 5 2013 and in December 18 2013, they had significant impact on some variables. The first is responsible for a 20 basis point increase in MBS yields and the second for a 3% drop in gold prices. Overall, the tapering announcements disrupted the financial markets and led to price changes, particularly for the assets concerned by the purchase programs. This is explained by the Fed's lack of communication ahead of these decisions, leading to strong surprise shocks for the market participants.

Turning to QT announcements, changes in all asset prices were unremarkable around the twelve announcements. If we look at treasuries and MBS yields, which had the potential to be directly affected by the reduction of Fed's holdings, none of them were significantly impacted by the central bank's announcements. There is just one exception for the announcement in 19 December, 2018. This day, U.S. equity markets suffered their worst reaction to a Fed rate hike since 1994 after Chair Jerome Powell said that the Fed's balance sheet reduction was on "auto-pilot". The effect of the announcement on U.S. equity prices is statistically significant. If we compare the effective drop of S&P 500 on these days (about 4%) and the effect of the announcement on S&P 500, we can conclude that the announcement is responsible for the entire underperformance of the index.

Therefore, this section confirms the results found previously. Except on the 19 December, 2018, QT has no effect on rates, asset prices, liquidity and volatility measures at the time of their announcements. This means that either (i) investors adjusted their prices in advance of the announcement and were therefore not surprised by the announcement and/or (ii) investors attach very little importance to the policy and believe that it will have no effect. The coefficients of the fed fund futures are significant for each of the OLS regressions, demonstrating that investors' attention is almost exclusively focused on the Fed's rate policy. They readjust their expectations regarding future rates hikes at each of FOMC meeting, depending of their interpretation of the tone of Jerome Powell. Each of its words and expressions are analysed to deduce the future path of monetary policy.

Table 13: Two-days change in yields (in basis points)

	UST 2y	UST 5y	UST 10y	UST 30y	MBS
May 5, 2013	1.27	7.43	8.75	6.07	19.23*
June 19, 2013	6.29	24.68***	23.23**	17.25**	34.12***
Dec. 18, 2013	4.27	15.16*	8.53	4.09	8.83
May 21, 2014	0.36	3.43	3.98	4.43	1.11
July 9, 2014	-4.74	-3.82	-1.87	0.00	-3.76
July 15, 2014	2.76	2.04	-1.84	-3.11	3.21
Sept. 17, 2014	2.46	5.58	2.30	-1.23	2.95
Oct. 29, 2014	6.97	5.52	0.76	-2.24	1.82
April 5, 2017	-0.84	-3.27	-2.37	-1.34	-0.12
May 24, 2017	-8.20	-9.32	-6.66	-5.56	-7.90
June 14, 2017	-0.76	-6.26	-8.72	-9.89	-0.78
Sept. 20, 2017	3.28	4.92	4.04	1.12	4.22
Dec. 19, 2018	-0.07	-1.71	-4.68	-7.18	-1.28
April 6, 2022	-4.47	-0.13	10.55	11.43	8.04
May 4, 2022	-2.80	2.34	10.54	16.07**	6.72

	Term premium	CBOE VIX	FRA-OIS	UST Liq.
May 5, 2013	10.43	4.83	-0.27	-0.05
June 19, 2013	13.33	23.00**	1.01	-49.36
Dec. 18, 2013	4.48	-13.31	0.41	-2.75
May 21, 2014	4.20	-7.66	-0.16	-7.92
July 9, 2014	-0.43	4.64	1.25	-5.55
July 15, 2014	-5.15	-7.35	-0.11	17.95
Sept. 17, 2014	-2.69	-6.09	-0.15	6.11
Oct. 29, 2014	-6.01	0.58	-0.70	1.93
April 5, 2017	-0.40	4.45	-0.43	-26.66
May 24, 2017	-1.87	-4.40	2.52	8.34
June 14, 2017	-6.01	4.43	-0.05	-9.06
Sept. 20, 2017	-0.43	-3.86	-0.78	-3.85
Dec. 19, 2018	-6.88	11.10	-24.07	9.56
April 6, 2022	24.74	1.81	1.97	-1.55
May 4, 2022	21.36	5.89	-0.05	7.68

Table 14: Two-days change in asset prices (in basis points)

	<b>Global Bond</b>	<b>HY</b>	<b>S&amp;P500</b>	<b>S&amp;P500 Banks</b>	<b>Risk Prem.</b>
May 5, 2013	0.00	-0.50	-0.99	-1.00	-1.08
June 19, 2013	-1.99***	-1.43**	-0.98	-3.80**	-3.78**
Dec. 18, 2013	-0.55	0.02	-0.75	1.54	0.79
May 21, 2014	-0.22	-0.13	-1.20	1.12	1.31
July 9, 2014	0.06	-0.29	-0.99	-0.20	0.17
July 15, 2014	-0.20	-0.25	-1.87	0.12	-0.03
Sept. 17, 2014	-0.29	0.24	-0.98	0.57	0.82
Oct. 29, 2014	-0.48	-0.08	-0.94	0.30	-0.29
April 5, 2017	-0.05	0.15	-1.01	-0.20	-0.52
May 24, 2017	0.23	-0.12	-0.41	-0.08	0.49
June 14, 2017	-0.09	-0.07	-1.84	-0.33	-1.00
Sept. 20, 2017	-0.38	0.03	-0.87	-0.22	-0.97
Dec. 19, 2018	0.41	-1.66***	-0.91	-2.22	-2.67
April 6, 2022	-0.64	-0.97	-1.02	-0.62	-2.10
May 4, 2022	-0.43	-0.23	-1.03	-0.69	-1.84

	<b>DXY</b>	<b>Gold</b>	<b>Brent</b>	<b>UST Bid-Ask</b>	<b>FSI</b>	<b>MOVE</b>
May 5, 2013	-0.09	0.97	-1.41	3.91	-2.95	15.06
June 19, 2013	1.42**	-5.95***	-3.59	2.25	-51.91	19.50
Dec. 18, 2013	0.69	-2.98*	1.28	5.43	13.45	0.13
May 21, 2014	0.21	-0.02	1.20	4.78	7.93	-1.97
July 9, 2014	-0.08	1.66	-0.34	4.80	-1.24	2.07
July 15, 2014	0.43	-0.57	0.26	4.78	0.29	-1.90
Sept. 17, 2014	0.19	-0.81	-2.04	5.85	9.68	-6.43
Oct. 29, 2014	0.85	-2.55	-0.48	3.96	35.02	-5.67
April 5, 2017	0.21	-0.42	1.22	6.13	-7.26	6.53
May 24, 2017	-0.37	0.45	-6.17	2.37	28.91	0.63
June 14, 2017	0.45	-1.12	-4.06	4.27	0.59	0.78
Sept. 20, 2017	0.49	-1.25	2.18	4.69	9.37	-2.18
Dec. 19, 2018	-0.91	1.17	-1.22	4.56	-18.6	0.29
April 6, 2022	0.27	0.53	-5.99	5.14	-21.97	6.58
May 4, 2022	0.27	0.21	5.46	5.37	38.65	-1.98

Notes: Coefficients  $\beta^{QE}$ ,  $\beta^{Taper}$  and  $\beta^{QT}$  from the regression:  $\Delta_{yt} = \beta^{QE_1} QE_{1t} + \beta^{QE_2} QE_{2t} + (...) + \beta^{Taper_1} Taper_{1t} + (...) + \beta^{QT_1} QT_{1t} + (...) + \alpha_1 X_1 + \alpha_2 X_2 + \epsilon_t$ , where  $\Delta_{yt}$  is the two-day change in the yield or percent change in asset price and  $QE_t$ ,  $Taper_t$  and  $QT_t$  are dummy variables, which takes a value 1 on the date of the individual event.  $X_1$  and  $X_2$ , the control variables correspond respectively to economic surprises and Fed fund futures.

OLS standard errors are reported in parenthesis. Sample Period: January 2008 – May 2022. Observations: 3712.  
 \*\*\* < 0.01, \*\* < 0.05, \* < 0.10.

QT 1: April 5, 2017 ; May 24, 2017 ; June 14, 2017 ; Sept. 20, 2017 ; Dec. 19, 2018.

QT 2: April 6, 2022 ; May 4, 2022.

## 4 Conclusion

According to Janet Yellen, quantitative tightening is supposed to be boring by design ( *"it'll be like watching paint dry"*, 2017), but there has been little empirical analysis of the financial market impact of balance sheet unwinding. The objective of this paper is to better understand this monetary policy dimension, at a time when several major central banks have initiated the normalization of their balance sheets. Our findings show strong asymmetries in the reaction of financial markets to balance sheet expansions, normalisation and unwinds. QE and Tapering events lead to strong variations in the price of all asset classes, while QT announcements had been fully anticipated by the market participants, as intended by the Fed. The strong revaluations of financial assets following QE announcements was the Fed's objective for QE, which used its communication to change market expectations and thus influence asset prices. The communication around tapering was, on the other hand, a monetary policy mistake, and has led the Fed to review the way it communicates this kind of policy. Our second main result is that none of these measures lead to financial instability at the time of their announcements, except QT which affects the liquidity of the Treasury market. This finding is consistent with the fact that QT drains liquidity from markets by removing a guaranteed buyer of massive amounts of debt securities. Thereby, despite asset price adjustments ahead of the announcements, liquidity in this market seems to be under stress following the announcements, as demonstrated by the bid-ask spread reaction. Moreover, the lack of financial markets effects around QT communication does not guarantee that this measure will not lead to disruptions in the markets as it is implemented. Bank's reserves level, money market and Treasury market liquidity must requires close monitoring by central bankers.



# General Conclusion

Since the global financial crisis of 2007-2008, there has been a significant transformation in the way monetary policy is implemented, with an increased use and awareness of central bank balance sheets. While the adoption of balance sheet policies have been staggering in terms of magnitude and rapidity, the change in operational frameworks have been more subtle. After more than a decade of experience with those policies, numerous academic papers demonstrated the effectiveness of these instruments in terms of (i) alleviating short-term funding market tensions, (ii) addressing monetary policy disruption in the transmission channels and (iii) providing additional monetary policy stimulus once the policy rate was constrained by the effective lower bound.

However, these instruments, whose use was initially intended to be temporary, became full-fledged monetary policy tools, alongside the main conventional instruments. Their prolonged use has led to profound changes in the monetary policy framework, with balance sheet size reaching unprecedented scale and balance sheet composition being radically altered. It created significant uncertainties regarding the impact of these instruments on financial market functioning. A protracted period of abundant liquidity may over time induce excessive risk-taking by financial intermediaries, create a dependence on central bank liquidity and artificially inflate financial asset prices. Although a key concern of those designing and implementing balance sheet policies, these effects on market functioning have received little attention in academic research.

Against this background, the goal of this thesis was to analyse the effects of the balance sheet policies on financial stability metrics. In particular, we have examined the extent to which financial stability has been affected by the advent of central bank balance sheet policies, focusing on banking systemic risk and equity market price misalignments. In line with this research question, we tested whether the use of these measures had generated such changes in the financial markets that the gradual withdrawal of these policies would lead to major market disruption.

In the first chapter, we evaluated the overall effect of exogenous innovations to the central banks' balance sheet on banking systemic risk and equity market price misalignments, in the eurozone, the United-States and in Japan, within a structural BVAR model. In a second step, we revisited the relationship between central bank balance sheet policies and systemic risk by adopting a firm-level approach, in order to investigate the potential heterogeneous effects of balance sheet shocks on financial firms' systemic risk. We found that balance sheet policies support financial stability in the short and medium run, and even in the long term for Japan. Moreover, financial institutions with the highest level of financial leverage benefit most from these monetary policies.

While we studied the aggregate effect of balance sheet policies on two financial stability indicators, the chapter 2 proposed to determine the effect of each monetary policy measures on financial stability. The main contribution of this work was to propose a new decomposition of monetary policy surprises by disentangling government bonds purchases programmes from more risky assets ones. To identify the monetary policy surprises, we used a sign restriction approach applied to factor identification. Then, we estimated impulse responses by Smooth Local Projections in order to assess the impact of these surprises on the SRISK and our measure of equity prices overvaluation. We showed that private asset purchase programs contribute more to financial system vulnerabilities than public ones. However, in the longer run, the effects of the two types of quantitative easing become insignificant, meaning that regardless of the nature and risk of the securities purchased, these measures do not seem to have side effects and to represent a durable threat to financial stability.

In the context of the shift from an ultra-accommodative policy to a restrictive one in 2022 for most of the central banks, the third chapter explored the effects of Fed's quantitative tightening announcements on asset prices and financial stability metrics, based on the 2017-2019 experience and the balance sheet unwinding started in June 2022. Our first contribution was to compare the announcements' effects of quantitative easing, tapering, and quantitative tightening. The second was to focus on the reaction of all asset classes and a palette of indicators of financial instability



risks to central bank's balance sheet communication. Our findings demonstrated strong asymmetries in the reaction of financial markets to balance sheet expansions, normalisation and unwinds. QE and Tapering events lead to strong reaction in prices of all asset classes, while QT announcements had been fully anticipated by the market players. These differences are the result of the way the Fed communicates its monetary policy decisions. Our second main result was that none of these measures lead to financial instability at the time of their announcements, except QT which affects the liquidity of the Treasury market. This finding is consistent with the fact that QT drains liquidity from markets by removing a guaranteed buyer of massive amounts of debt securities.

To summarize, our analysis provided comprehensive evidence that the deployment and the prolonged use of balance sheet policies has not given rise to a degradation of financial stability, whether in terms of systemic banking risk or equity price misalignments. On the contrary, these policies have fulfilled their objectives and maintained the stability of the financial system. This success in the prolonged use of these balance sheet policies would not have been possible without the strength of central bank communication. Central banks have always been careful to communicate clearly and transparently about the use of their tools and their objectives. The slightest mistake in terms of communication or tone used by central bankers translates into disorder on the financial markets, as happened during the Taper Tantrum in June 2013. While policies have helped to maintain financial stability, they have also given rise to new behaviors and characteristics among financial system players, which could be a source of financial instability throughout the process of exit of these measures.

Therefore, there are several avenues for future research on the process of unwinding of central banks' balance sheet policies. First, one of them could be to study the effects of the Fed quantitative tightening in the medium and long term on financial markets, especially in the context of the replenishment of the Treasury General Account (TGA). As the US government has drawn down their TGA to keep running as the debt ceiling prevents large issuance of bonds to fund spending, mechanically bank reserves are released into the system. But now the debt ceiling story is solved, the Treasury need to rapidly replenish their TGA and quantitative tightening will keep running on

the background. As a consequence, liquidity is projected to consistently decline throughout 2023 and 2024, which could jeopardize further balance sheet reduction.

Moreover, if the side effects of balance sheet policies become apparent over the long term, a greater macroprudential oversight should be imposed. The monetary policy and the macroprudential policy have large interactions because they both operate through the financial system. It is important to choose an appropriate policy mix, either to reinforce the effectiveness of one instrument, or to mitigate its side effects on one of the objectives of these two policies. For example, the effects of monetary policy easing on bank lending and risk-taking are greater when macroprudential policy is accommodative and are particularly strong for less capitalised banks. In contrast, macroprudential policy may need to further tighten during the central bank liquidity build-up to keep the likelihood of systemic financial distress in check, relative to a scenario with a less ex-post expansionary monetary policy. Thus, depending on the objective, the macroeconomic and financial context and the underlying risks, monetary and macroprudential policy can act in a complementary manner, either to reinforce the effectiveness of one or to offset its side effects.



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# Appendix A - Chapter 1

## A.1 Details of new identification schemes for monetary policy

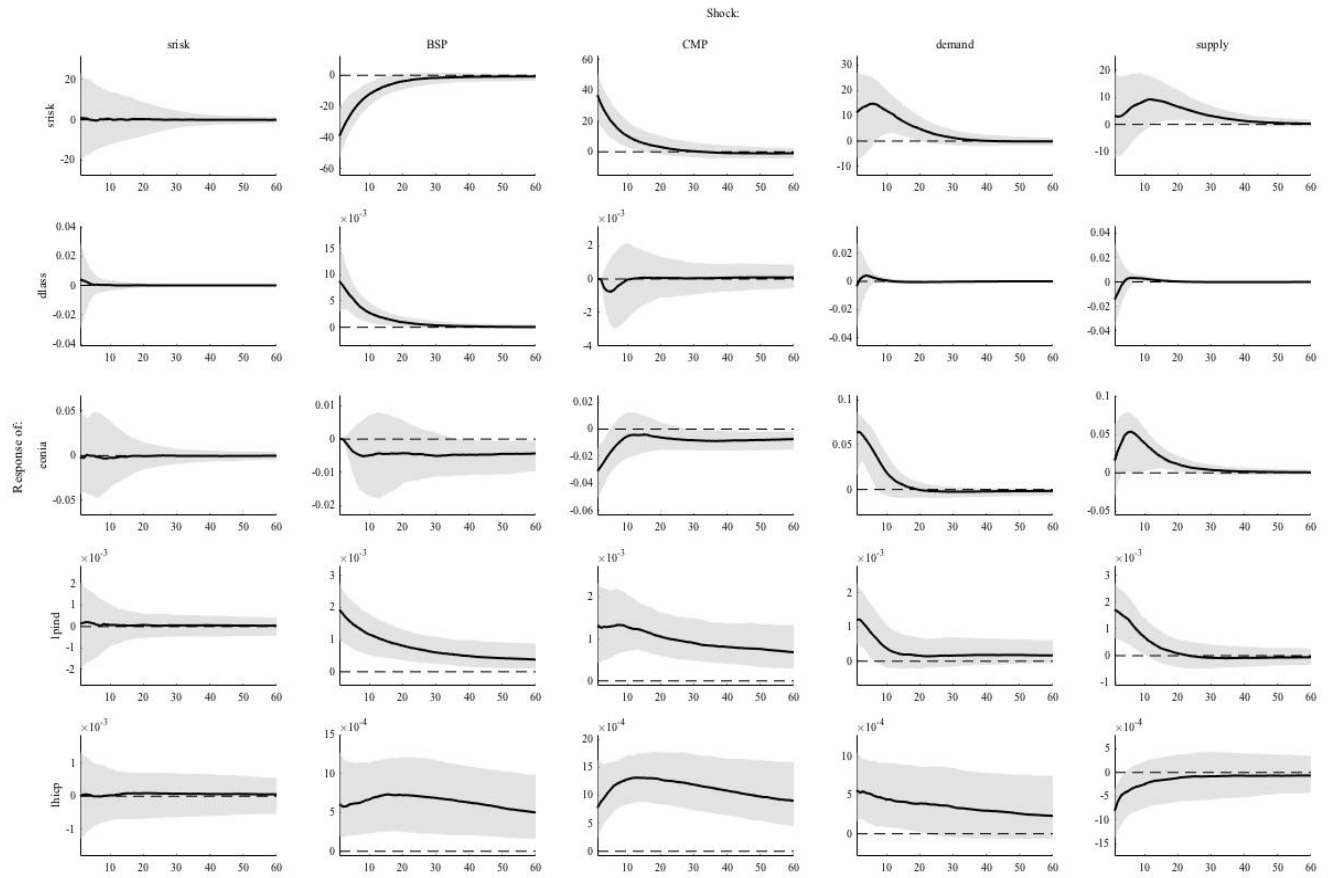
New identification schemes that are suitable at the zero lower bound have been developed following the 2007-08 financial crisis, but there is still no consensus on the most appropriate method for measuring monetary policy shocks. Among these methods, Krippner (2013) and Wu & Xia (2016) have proposed **shadow rate** measures of interest rates to quantify the stance of monetary policy in unconventional times. The shadow rate measure, can be defined as the shortest maturity rate, extracted from a term structure model, that would generate the observed yield curve had the effective lower bound not been binding. An embedded and somewhat hidden assumption of shadow rates is that every unconventional monetary policy action only matters to the extent that it affects the term structure of government bond yields, especially its long end (Lombardi & Zhu, 2018). Much of the recent empirical working on the effects of unconventional monetary policy has taken the **event-study approach** (Kuttner, 2001 ; Bernanke & Kuttner, 2005) by measuring financial market responses to monetary policy announcements (Altavilla and Giannone, 2014). This method consists of identifying monetary policy shocks as the changes in financial markets expectations on a short window of time around a monetary policy announcement. Another approach, built on the literature on the effects of monetary policy announcements using high-frequency identification, is via a **VAR with functional shocks** (Inoue and Rossi, 2018), where the shock is the exogenous shift in the yield curve due to monetary policy. It allows to capture several dimensions of monetary policy such as forward guidance and asset purchases programs and captures only monetary policy changes that are fully unexpected by financial markets. This approach differs from event-study approach, which focus only on the effects of monetary policy on yields at specific maturities, by focusing on the change in both the shape and the magnitude of the whole yield curve, not only . A potential issue faced by these types of identification is that the identified shocks may not be

pure monetary policy shocks, since they might be contaminated by other shocks or information that the central bank is releasing about the future state of the economy in their announcements (Rossi, 2018). New methods have been developed that allow researchers to clean the shocks from informational effects by regressing them on Central bank's own forecasts (Miranda-Agrippino & Ricco, 2018; Jarocinski and Karadi, 2018). More precisely, they **combine the high-frequency identification** of Gertler and Karadi (2015) and Romer and Romer (2004)'s **narrative approach** and propose a novel instrument for monetary policy shocks that takes into account both the slow absorption of information in the economy, and the signalling channel of monetary policy that arises from the asymmetry of information between the central bank and market participants. **Sign and zero restriction** are also typically used for identification in the literature analyzing unconventional monetary policy (Gambacorta, Hofman and Peersman, 2014 ; Weale and Wieladeck, 2016 ; Haldane et al., 2016 ; Boeckx, Dossche and Peersman, 2017 ; Burriel and Galesi, 2018 ; Lewis and Roth, 2019). As the theoretical foundations of balance sheet policies are not well established, both the signs and their restriction horizons are inevitably arbitrary. Moreover, a recent debate has emerged in the literature on the relevance of this method to the identification of unconventional monetary policy shocks. Elbourne and Ji (2019) question the results of Gambacorta & al (2014), Boeckx et al (2017), Burriel and Galesi (2018). The restrictions imposed in these three studies are as follows: an expansionary unconventional monetary policy shock increases the size of the central bank balance sheet, reduces financial stress and the EONIA-MRO spread, and has no contemporaneous effect on activity and prices. The main result of Elbourne & Ji (2019) is that by replacing the size of the balance sheet with a series of random numbers, the response functions are only slightly modified. Another argument is the low correlation between shocks that are identified with sign and zero restrictions method and those identified from futures rate surprises by Jarocinski & Karadi (2018) and Corsetti & al. (2018). They conclude that response functions do not depend on the information contained in the size of the central bank's balance sheet and, therefore, that the identification method does not distinguish monetary policy shocks from other shocks that result in a reduction in financial stress. In response to this paper, Boeckx, Dossche, Galesi, Hofmann and Peersman (2019) reproduce their results using the SVAR model of Boeckx et al (2017) and counter

each of their arguments. In particular, in response to the key argument of Elbourne & Ji (2019), they argue that the identified shock by replacing data on the size of the balance sheet with a series of random numbers, is a linear combination of the original unconventional monetary policy shock and another shock that eases financial conditions. These two shocks would be expected to have expansionary macroeconomic effects. Regarding their second argument, Boeckxx & al. justify it by the fact that identified shocks are fundamentally different: short-term interest rate surprises in the case of event studies and unconventional monetary policy measures that expand the central bank balance sheets and are orthogonal to changes in the policy rate in the case of sign and zero restrictions' identification.

# A.2 Euro Area - Impulse Responses Functions (SRISK)

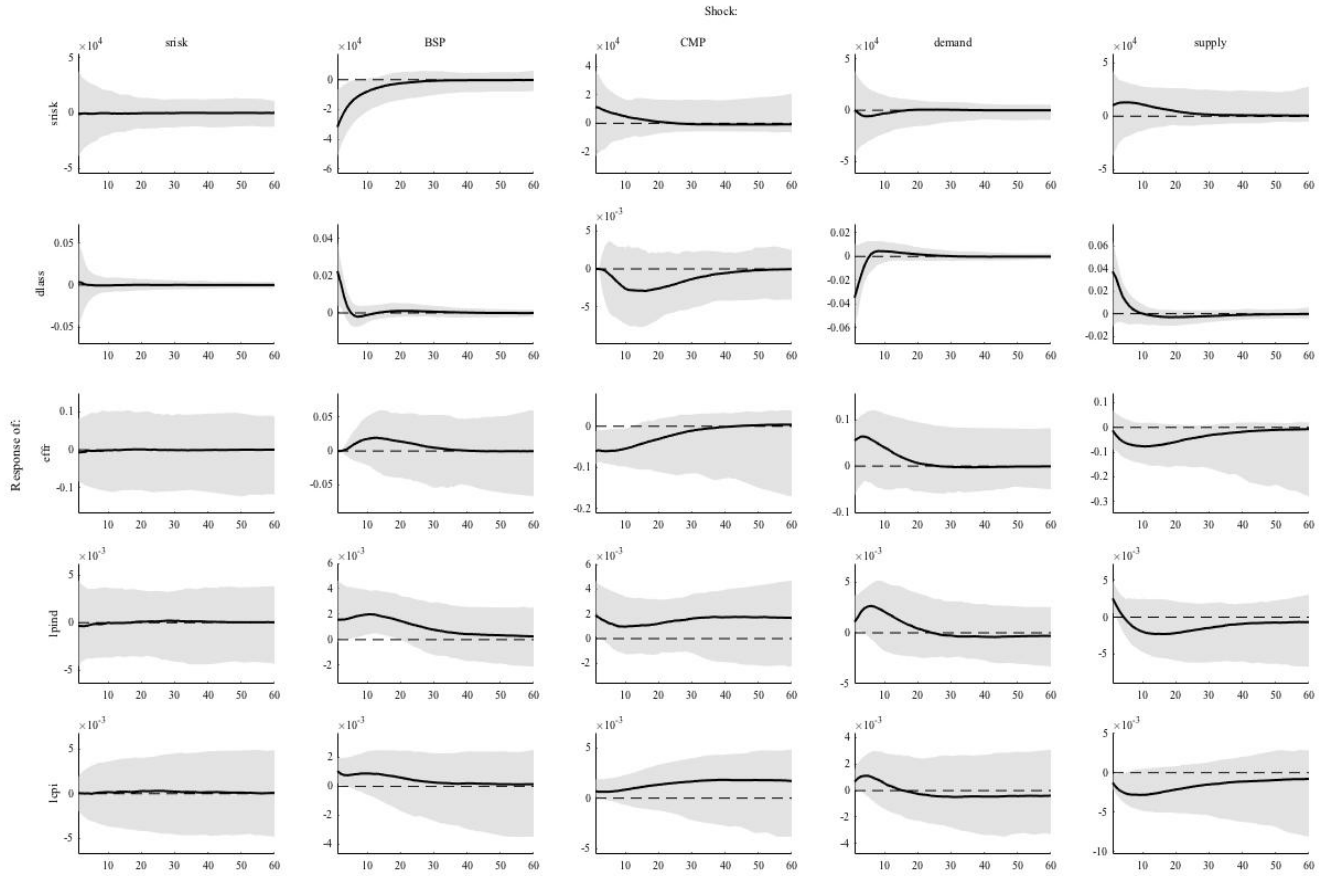
Figure 30: Impulse Responses Functions (09.2008 - 12.2018)



Notes: Results for the model with the Srisk – Euro Area. This figure shows, for each of the variables list above, the median impulse responses in response to an unexpected shock (srisk shock in the first column, bsp shock in the second column, CMP shock in the 3rd column, demand shock in the 4th column and supply shock in the 5th column), together with 95% Bayesian credible sets.

# A.3 United-States - Impulse Responses Functions (SRISK)

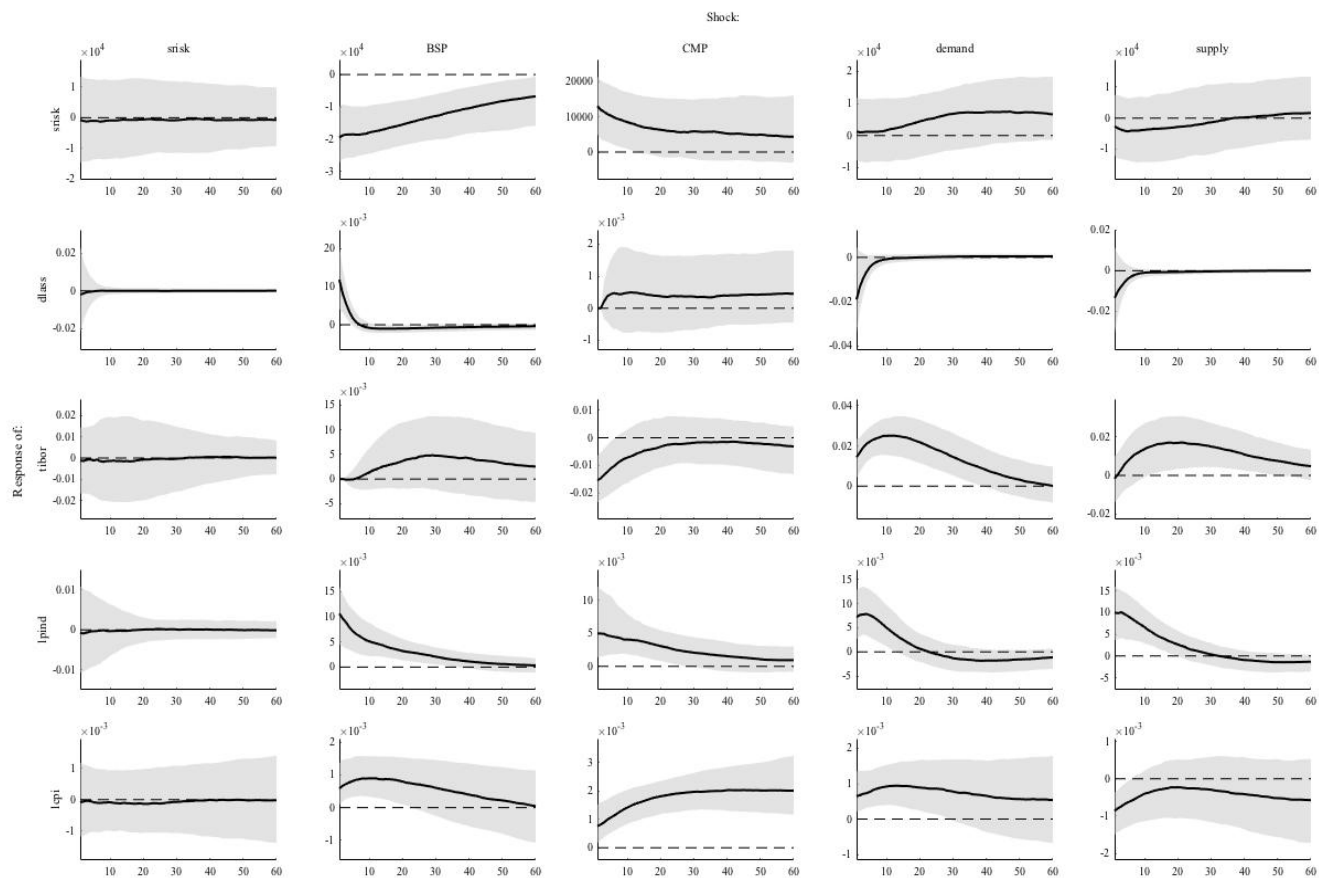
Figure 31: United-States - Impulse responses function (09.2008 - 12.2018)



Notes: Results for the model with the Srisk – United-States. This figure shows, for each of the variables list above, the median impulse responses in response to an unexpected shock (srisk shock in the first column, bsp shock in the second column, CMP shock in the 3rd column, demand shock in the 4th column and supply shock in the 5th column), together with 95% Bayesian credible sets.

# A.4 Japan - Impulse Responses Functions (SRISK)

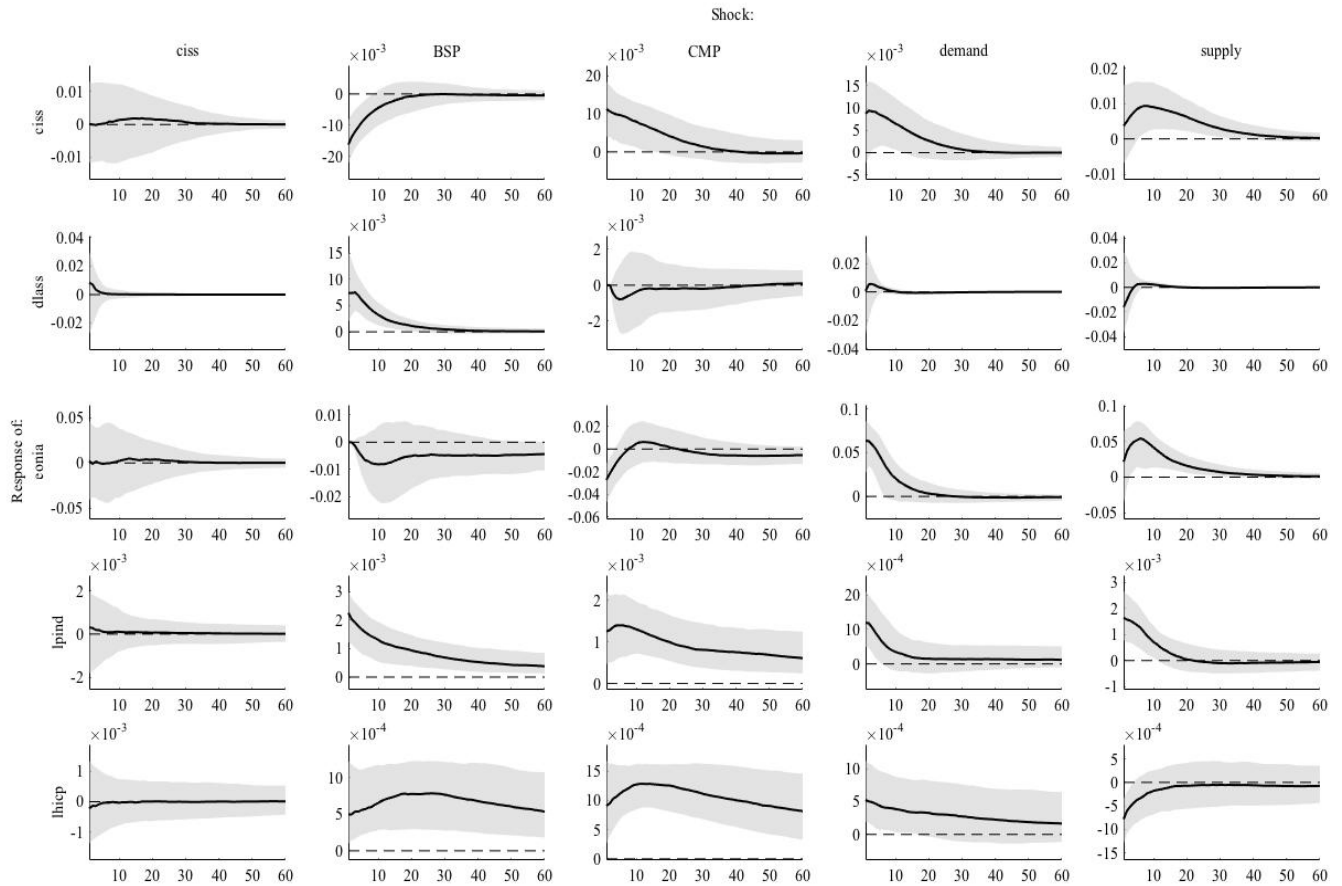
Figure 32: United-States - Impulse responses function (01.2008 - 12.2018)



Notes: Results for the model with the *Srisk* – Japan. This figure shows, for each of the variables list above, the median impulse responses in response to an unexpected shock (*srisk* shock in the first column, *bsp* shock in the second column, *CMP* shock in the 3rd column, *demand* shock in the 4th column and *supply* shock in the 5th column), together with 95% Bayesian credible sets.

# A.5 Euro Area - Impulse Responses Functions (CISS)

Figure 33: Euro Area - Impulse responses function (01.2008 - 12.2018)

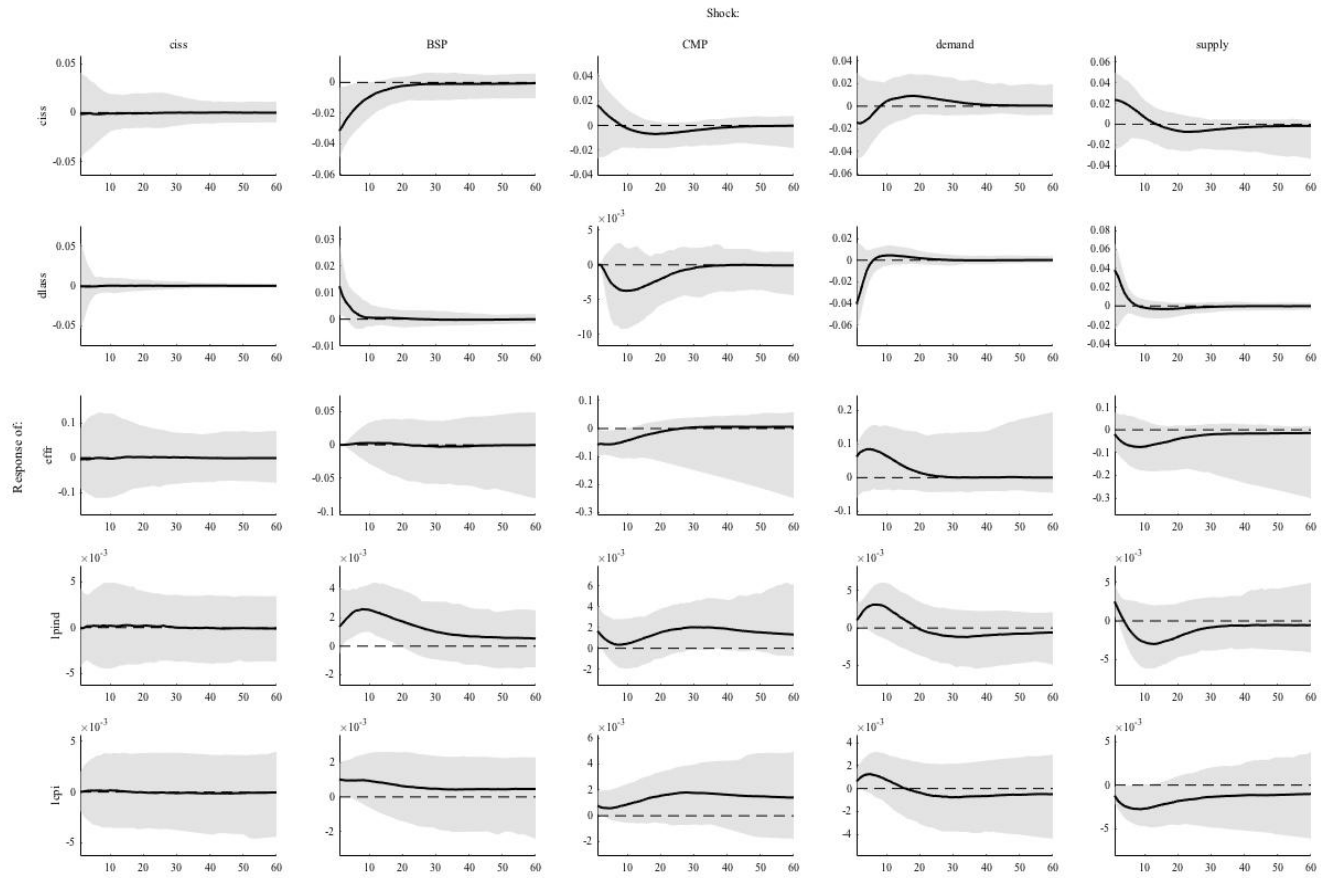


Notes: Results for the model with the CISS – Euro Area. This figure shows, for each of the variables list above, the median impulse responses in response to an unexpected shock (ciiss shock in the first column, bsp shock in the second column, CMP shock in the 3rd column, demand shock in the 4th column and supply shock in the 5th column), together with 95% Bayesian credible sets.



# A.6 United-States - Impulse Responses Functions (CISS)

Figure 34: United-States - Impulse responses function (01.2008 - 12.2018)



Notes: Results for the model with the CISS – United-States. This figure shows, for each of the variables list above, the median impulse responses in response to an unexpected shock (srisk shock in the first column, bsp shock in the second column, CMP shock in the 3rd column, demand shock in the 4th column and supply shock in the 5th column), together with 95% Bayesian credible sets.

## A.7 Figures of asset price bubbles indicator in the U.S., the EA & in Japan

Figure 35: U.S. - Asset price bubbles indicator



Notes: Composite indicator of asset price bubbles (S&P 500), computed from 3 different approaches (structural, data-drive and statistical).

Figure 36: Euro area - Asset price bubbles indicator



Notes: Composite indicator of asset price bubbles (Euro Stoxx 50), computed from 3 different approaches (structural, data-drive and statistical).

Figure 37: Japan - Asset price bubbles indicator



Notes: Composite indicator of asset price bubbles (Nikkei 225), computed from 3 different approaches (structural, data-drive and statistical).

## A.8 Section 2 - Financial institutions sample

Table 15: Sample of financial institutions

	<b>The 12 with the lowest leverage</b>	<b>The 12 with the highest leverage</b>
<b>Euro area</b>	Banco di Sadergna SpA, Luxempart SA, Brederode SA, Sofina SA, Corp Financiera Alba SA, Gimv NV, Grivalia Properties REIC AE, Union Financiere de France BQE SA, Wereldhave Belgium NV, OVB Holding AG, Financiere de Tubize SA, Hellenic Exchanges - Athens Stock Exchange SA, DeA Capital SpA	Societe Generale SA, Wuestenrot & Wuerttembergische AG, Aareal Bank AG, Natixis SA, Bank of Ireland Group PLC, Deutsche Bank AG, Piraeus Bank SA, Credit Agricole SA, Eurobank Ergasias SA, Commerzbank AG, Dexia SA
<b>United States</b>	T Rowe Price Group Inc, Cohen & Steers Inc, SEI Investments Co, MasterCard Inc, Franklin Resources Inc, Federated Hermes Inc, Waddell & Reed Financial Inc, Eaton Vance Corp, Moody's Corp, Equifax Inc, Brown & Brown Inc, Marsh & McLennan Cos Inc	MetLife Inc, American International Group Inc, E*TRADE Financial Corp, Bank of America Corp, Prudential Financial Inc, Lincoln National Corp, Morgan Stanley, Hartford Financial Services Group Inc/The, CNO Financial Group Inc, SLM Corp, Citigroup Inc, Genworth Financial Inc
<b>Japan</b>	Aeon Mall Co Ltd, Mitsubishi Estate Co Ltd, Mitsui Fudosan Co Ltd, Matsui Securities Co Ltd, NTT Urban Development Corp, Acom Co Ltd, Sumitomo Realty & Development Co Ltd, Nomura Real Estate Holdings Inc, Tokyo Tatemono Co Ltd, AEON Financial Service Co Ltd, Tokio Marine Holdings Inc, ORIX Corp	Gunma Bank Ltd/The, Shinsei Bank Ltd, Hiroshima Bank Ltd/The, Sumitomo Mitsui Trust Holdings Inc, Mitsubishi UFJ Financial Group Inc, Sumitomo Mitsui Financial Group Inc, Shiga Bank Ltd/The, Shinkin Central Bank, Resona Holdings Inc, 77 Bank Ltd/The, Mizuho Financial Group Inc, Hokuhoku Financial Group Inc

Notes: Our three samples contain the financial institutions whose srisk is calculated by the V-lab institute including depositories, broker-dealers, insurance, non depository institutions and real estate.

## A.9 Descriptive Statistics

Table 16: Descriptive statistics (sample with the lowest level of financial leverage)

		<b>Euro area</b>	<b>United States</b>	<b>Japan</b>
Leverage	mean	1.19	1.22	4.21
	sd	0.24	0.17	2.36
	min.	1	1.01	1.30
	med.	1.12	1.19	3.54
	max.	5.03	2.02	38.32
SRISK	mean	-832.85	-8676.58	-3343.30
	sd	742.20	14872.43	4202.62
	min.	-4600.30	-131156.20	-22341.40
	med.	-574.65	-3263.20	-1595.35
	max.	-28.70	-174.70	4870
LRMES	mean	30.37	41.10	37.68
	sd	10.81	7.63	6.48
	min.	-4.98	22.44	18.54
	med.	29.80	42.39	37.49
	max.	83.63	63.67	63.64
Market cap.	mean	1309.31	16055.26	10610.73
	sd	1169.95	26520.60	9872.09
	min.	170.53	373.82	714.30
	med.	812.24	6265.16	4828.70
	max.	6890.44	231169.90	45120.55
<i>Observations</i>	<i>3168</i>	<i>3168</i>	<i>3168</i>	<i>3168</i>

Source: V-lab institute.

Table 17: Descriptive statistics (sample with the highest level of financial leverage)

		<b>Euro area</b>	<b>United States</b>	<b>Japan</b>
Leverage	mean	417.38	18.28	33.49
	sd	1945.61	16.16	10.80
	min.	1.80	3.30	11.57
	med.	45.64	14.31	32
	max.	22740.52	219.45	82.03
SRISK	mean	32132.53	21639.86	35529.38
	sd	38692.46	29692.10	47425.16
	min.	-4551	-48228.90	1411
	med.	12202.10	9708.05	8424.80
	max.	170166.90	154312.50	184029.50
LRMES	mean	50.30	47.64	29.52
	sd	15.33	10.58	13.28
	min.	11.52	11.74	-23.11
	med.	52.36	47.05	32.62
	max.	94.93	98.03	59.91
Market cap.	mean	12687.42	43379.44	18423.51
	sd	14534.84	55493.58	24687.65
	min.	8.38	169.97	1083.62
	med.	6786.11	18661.15	5929.64
	max.	68261.16	329193.68	119054.52
<i>Observations</i>	<i>3168</i>	<i>3168</i>	<i>3168</i>	<i>3168</i>

Source: V-lab institute.

# Appendix B - Chapter 2

## B.1 Fed & ECB Monetary Policy

### Instruments Description

Figure 38: EA - Main interest rates and forward guidance announcements

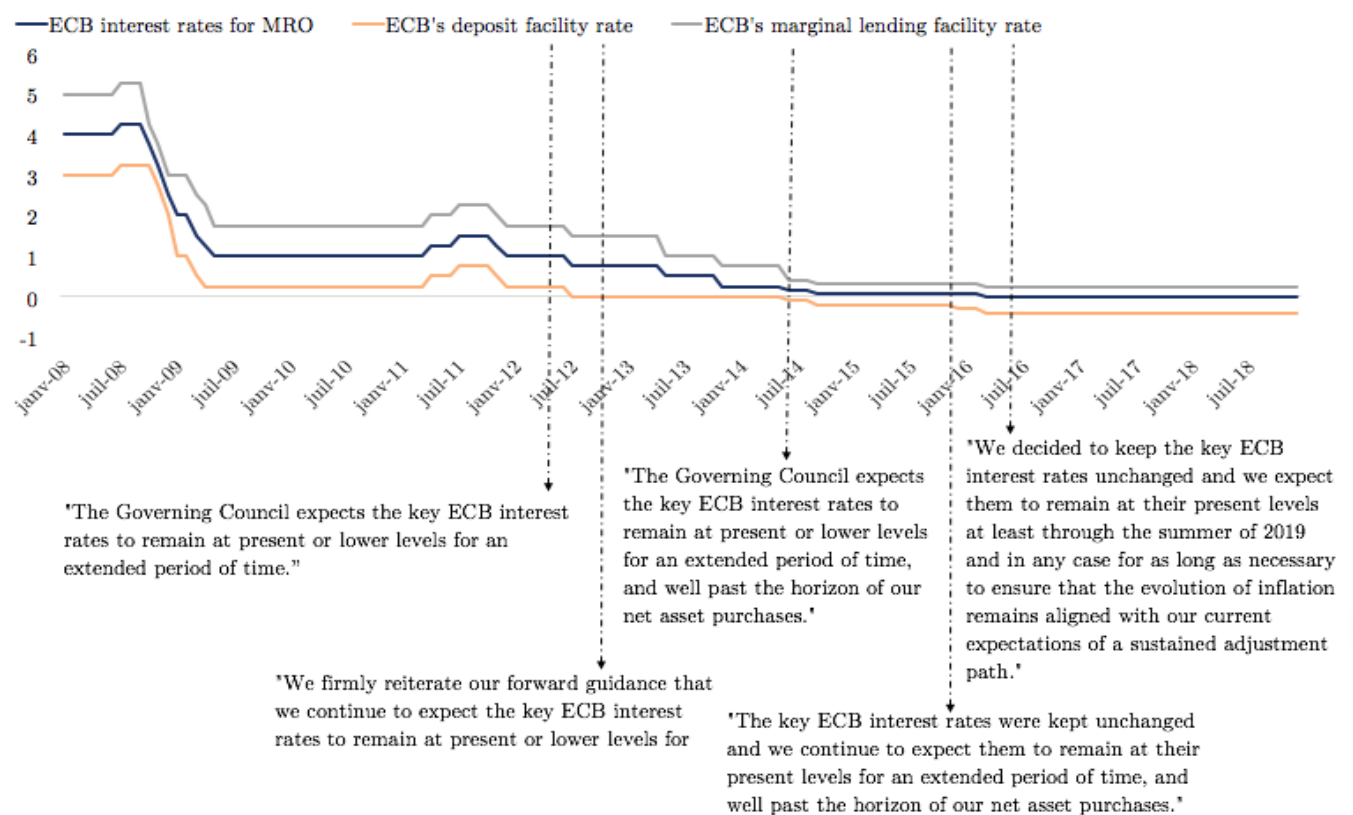


Figure 39: U.S. - Federal fund rate and forward guidance announcements

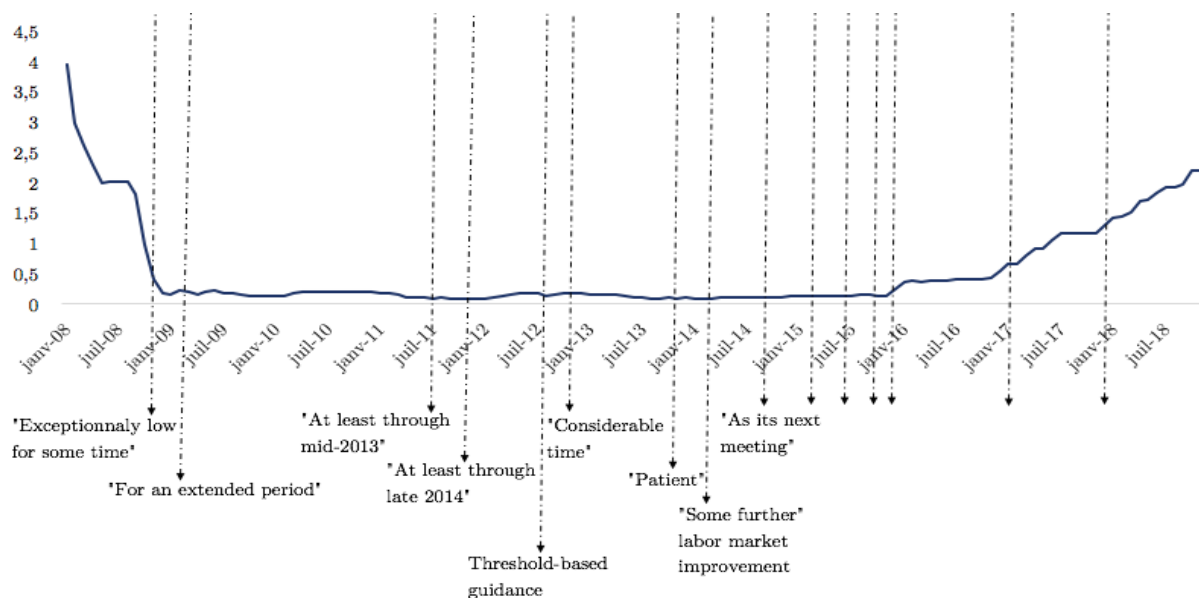


Figure 40: EA - Cumulative net purchases (Source: ECB)

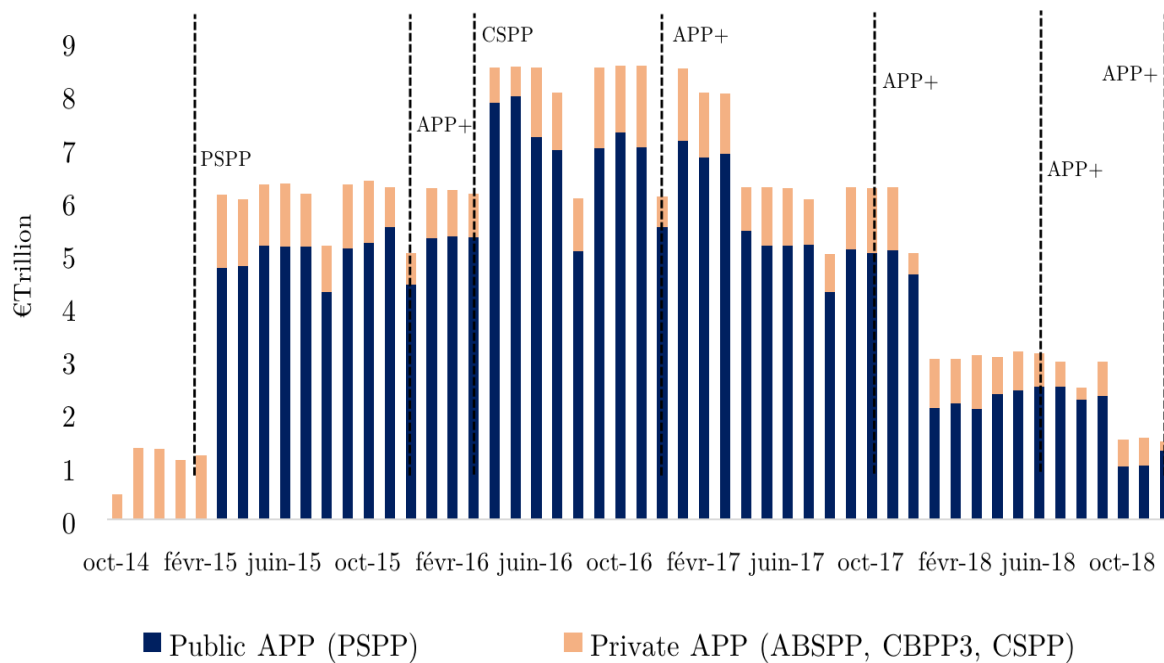
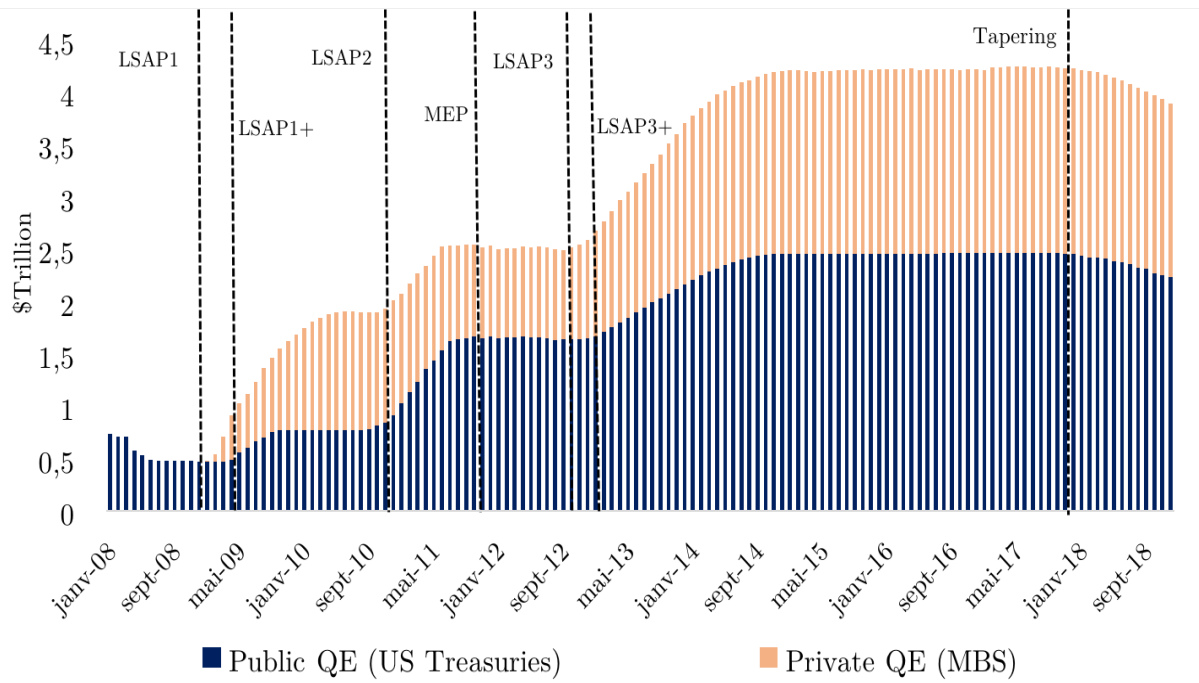




Figure 41: U.S. - Cumulative net purchases (Source: FRED, Federal Reserve Board)



## B.2 Details of identifying restrictions

Our identifying strategy of the various monetary policy types follows Swanson (2021) to identify a rotation that maps the four principal components of asset price responses to the Fed and the ECB announcements into four factors that have a structural interpretation as 1) the surprise change in the official rates (target); 2) the surprise change in forward guidance (forward guidance); 3) the surprise change in public securities purchase programs (public QE); and 4) the surprise change in private securities purchase programs (private QE). Let denote  $F$  the  $T \times 4$  matrix of the first four principal components, and  $\Lambda$  the  $4 \times n$  matrix of loadings of the asset price data on  $F$ . We aim at finding a 4 orthogonal matrix  $U$  that maps  $F$  into the four factors  $F^* \equiv FU$ . The first identifying assumptions are that forward guidance, public and private QEs have no impact on the official central bank's rate. These restrictions can be written as

$$U' \Lambda_1 = \begin{bmatrix} \cdot \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (16)$$

where  $\Lambda_1$  denotes the first column of  $\Lambda$ , the loadings of the current-month official rates on the four factors  $F$ . These restrictions imply that only the first factor has any systematic effect on the official central bank's rate. Moreover, to distinguish between public and private QE programs, we impose the restriction that private QE leads to a decrease in the corporate bond spread, while public QE leads to both a decrease in the 10-year Treasury yields and an increase in the corporate bond spread. To implement these restrictions computationally, we follow the code of Swanson (2021) that we adapt to account for the QE restrictions, which are at the core of our contribution. In more detail, we start with applying to the third and fourth factors both the zero and the sign restrictions. We start the procedure by taking the QR decomposition of a random matrix, where each element has an independent standard distribution. This yields  $\hat{F} = FQ$ . See Rubio-Ramirez, Waggoner, and Zha (2010) for details. We then rotate  $FQ$  to introduce the zero restrictions,  $u_{31} = u_{41} = 0$ , by post-multiplying with two Givens rotations matrices:

$$FQG_1(\theta_1^*)G_2(\theta_2^*) \equiv FQ_G \equiv \tilde{F} \quad (17)$$

where the Givens rotations are functions of the angles  $\theta_1^*$  and  $\theta_2^*$ . These two angles can be found by solving the system of two simultaneous equations obtained by setting the (3, 1) and (4, 1) elements of  $\tilde{F}$  to zero. In this step, we check whether the non-zero elements in  $\tilde{F}$  match the sign restrictions on the corporate bond loadings (negative for private QE and positive for public QE) as well as on the 10-year bond yields for public QE (negative). If yes, we keep  $\tilde{F}$  (and  $Q$ ) and we repeat the procedure until 100 matches have been found. Following Fry and Pagan (2011), we pick one rotation matrix which yields structural QE factors that are the most closely related to the median factors. After rescaling the two factors to have a unit length, We call the resulting vectors  $U_3$  and  $U_4$ , corresponding respectively to the public and private QE factors.

To implement the forward guidance restriction, we temporary ignore the unit length requirement on  $U_2$  and normalize its fourth element to unity. We then solve the equation

$$\begin{bmatrix} \Lambda_1' \\ U_3' \\ U_4' \end{bmatrix} \begin{bmatrix} u_{12} \\ u_{22} \\ u_{23} \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad (18)$$

for  $u_{12}$ ,  $u_{22}$  and  $u_{32}$ , which ensures that  $[u_{12} \ u_{22} \ u_{23} \ 1]'$  satisfies the identifying restriction and is orthogonal to  $U_3$  and  $U_4$ . We then rescale the vector  $[u_{12} \ u_{22} \ u_{23} \ 1]'$  to have a unit length and call the result  $U_2$ .

Finally, we compute the Target factor,  $U_1$ , similarly, normalizing the fourth element of  $U_1$  to unity, solving the equation

$$\begin{bmatrix} U_2' \\ U_3' \\ U_4' \end{bmatrix} \begin{bmatrix} u_{11} \\ u_{12} \\ u_{13} \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad (19)$$

and renormalizing  $[u_{11} \ u_{12} \ u_{13} \ 1]'$  to have a unit length and call the result  $U_1$ . This ensures  $U_1$ , the Target factor, is orthogonal to  $U_2$ , the Forward Guidance factor, and to  $U_3$  and  $U_4$ , the two QE factors.

This procedure uniquely identifies  $U$  and  $F^*$  up to a sign normalization for each column. We

normalize the sign of the first column of  $F^*$  to have a positive effect on the current federal funds rate and the second column to have a positive effect on the four-quarter ahead Eurodollar futures contracts (ED4) for the U.S. and the 1-year OIS (OIS1Y) for the euro area. The third and the fourth columns have already the correct sign on the corporate bond spreads and on the 10-year bond yields, as defined in our sign restriction procedure.

## B.3 Figures of asset price bubbles indicator in the U.S. & in the EA

Figure 42: U.S. - Asset price bubbles indicator



Figure 43: Euro area - Asset price bubbles indicator

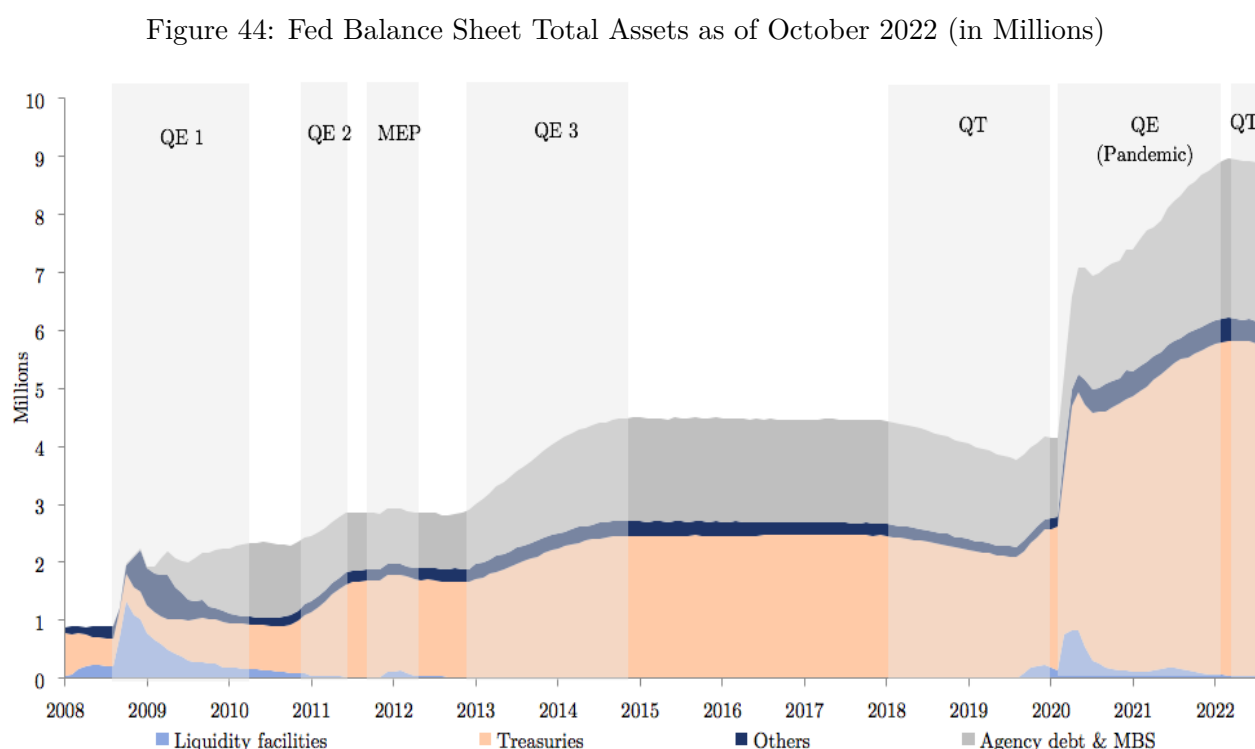


Notes: Composite indicator of asset price bubbles (S&P 500 & Euro Stoxx 50), computed from 3 different approaches (structural, data-drive and statistical).

# Appendix C - Chapter 3

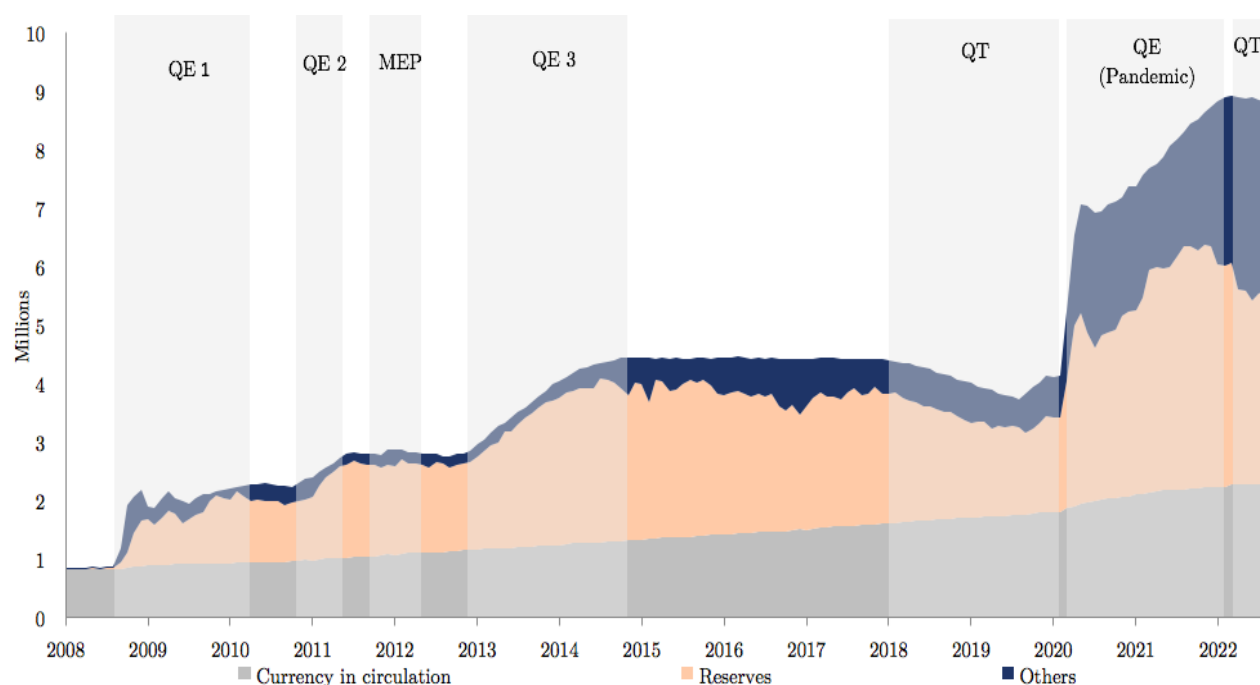
## C.1 Federal Reserve Balance Sheet

### total assets



Source: Federal Reserve Board

Figure 45: Fed Balance Sheet Total Liabilities as of October 2022 (in Millions)



Source: Federal Reserve Board

Table 18: Federal Reserve Bank balance sheet items variation as of 2.8.23 (USD bn)

Balance sheet items	2/8/23	2/9/22	1m change	1y change
<b>Assets</b>				
SOMA Holdings	7923	8321	-75	-398
T-bills	285	326	-3	-41
Treasury Notes & bonds	4612	4917	-49	-305
Treasury FRNs	23	29	-4	-6
TIIPS	375	385	-2	-10
Federal Agency Debt	2	2	0	0
Agency MBS	2616	2652	-17	-35
Agency CMBS	8	9	0	-1
Total Assets	8435	8878	-73	-443
Discount window borrowings	4	0	1	4
<b>Liabilities</b>				
Reserves	3038	3772	-44	-734
Treasury General Account	496	679	149	-183
Overnight RRP	2043	1653	-156	390
Foreign RRP	359	255	11	105
Other Deposits	192	241	-3	-48

## C.2 Major QE, Tapering & QT events & between 2008 - 2022

Table 19: Major QE events by the Federal Reserve, 2008 -2022

Date	Description
25.11.2008	Fed announces its intention to purchase up to \$100 billion of agency debt securities and up to \$500 billion of agency MBS.
01.12.2008	Bernanke stated Fed “could purchase longer-term Treasury or agency securities.”
16.12.2008	Fed cuts Fed funds rate target from 1% to 0–0.25%, was “ready to expand its purchases of agency debt and MBS as conditions warrant”, and suggested of extending QE to Treasury purchases.
28.01.2009	Fed was ready to expand the quantity and duration of MBS purchases.
18.03.2009	FOMC “will purchase up to an additional \$750 billion of agency MBSs with a total of \$1.25 trillion, up to \$100 billion agency debt this year with a total of \$200 billion and up to \$300 billion longer-term Treasury securities over the next six months.”
10.08.2010	FOMC states that it will keep constant the Federal Reserve’s holdings of securities at their current level "by reinvesting principal payments from agency debt and agency MBS in longer-term Treasury securities" and by continuing to roll over its holdings of Treasury securities as they mature.
27.08.2010	Bernanke suggested additional QE “should further action prove necessary.”
21.09.2010	FOMC “is prepared to provide additional accommodation if needed.”
15.10.2010	Bernanke commented the drawbacks of large scale asset purchases.
03.11.2010	FOMC announces its LSAP2 (purchase of an additional \$600 billion in longer-term Treasury securities at "a pace of about \$75 billion per month."
09.08.2011	FOMC “is prepared adjust those (securities) holdings as appropriate.”
21.09.2011	FOMC announces a maturity extension program (MEP) under which it will sell Treasury securities with a remaining maturity of 3 years or less and use the proceeds to buy Treasury securities with a remaining maturity of 6 to 30 years.
20.06.2012	FOMC states that it will extend its ongoing MEP through the end of 2012 by continuing to purchase longer-term securities at the current pace of about \$45 billion per month, while simultaneously selling or redeeming corresponding amounts of shorter-term Treasury securities.



22.08.2012	In FOMC Minutes, FOMC members “judged that additional monetary accommodation would likely be warranted fairly soon.”
13.09.2012	FOMC announces its LSAP3, an open-ended purchases of \$40 billion per month in MBS.
16.03.2020	The Committee will increase its holdings of Treasuries by at least \$500 billion and its holdings of agency MBS by at least \$200 billion over the coming months.
23.03.2020	The Fed will increase its holdings of Treasury securities and agency MBS in the amounts needed to support the smooth functioning of markets for Treasury securities and agency MBS.
10.06.2020	The Fed will increase its holdings of Treasury securities and agency residential and commercial MBS at least at the current pace to sustain smooth market functioning.

Table 20: Major Tapering events by the Federal Reserve, 2008 -2022

<b>Date</b>	<b>Description</b>
22.05.2013	During the Q&A for his testimony, Bernanke says that the FOMC "could in the next few meetings, take a step down in its pace of purchases" if its members see continued improvement and expect that improvement to be sustained.
19.06.2013	Bernanke remarks that the FOMC "currently anticipates that it would be appropriate to moderate the monthly pace of purchases later this year."
18.12.2013	FOMC announces it will start to taper its purchases of MBS and longer-term Treasuries to a pace of \$35 billion and \$40 billion per month, respectively, and will "likely reduce the pace of asset purchases in further measured steps at future meetings."

Table 21: Major Quantitative Tightening events by the Federal Reserve, 2008 -2022

<b>Date</b>	<b>Description</b>
21.05.2014	FOMC Minutes signals beginning of balance sheet normalization planning.
09.07.2014	FOMC Minutes discusses gradual approach to ceasing asset reinvestments.
15.07.2014	Yellen said “it will make further measured reductions in the pace of asset purchases at upcoming meetings.”
17.09.2014	FOMC releases Policy Normalization Principles and Plan. The FOMC “Beginning in October ... will add to its holdings of agency MBSs ... \$5 billion rather than \$10 billion per month, long-term Treasury securities ... \$10 billion rather than \$15 billion per month.”
29.10.2014	FOMC announces that it will "conclude its asset purchase program this month." The policy of reinvesting the principal of maturing securities is maintained.
05.04.2017	FOMC Minutes state "most participants judged that a change to the Committee's reinvestment policy would likely be appropriate later this year," and that "reductions in the Federal Reserve's securities holdings should be gradual and predictable, and accomplished primarily by phasing out reinvestments."
24.05.2017	FOMC Minutes detail plan for phasing out reinvestment.
14.06.2017	FOMC states that it "expects to begin implementing a balance sheet normalization program this year."
20.09.2017	FOMC announces that, "in October, the Committee will initiate the balance sheet normalization program described in the June 2017”
19.12.2018	Powell states: “We would effectively have the balance sheet runoff on automatic pilot.”.
06.04.2022	FOMC Minutes state “Participants generally agreed that monthly caps of about \$60 billion for Treasury securities and about \$35 billion for agency MBS would likely be appropriate”.
04.05.2022	FOMC decides to begin reducing its holdings of Treasury securities and agency debt and agency MBS on June 1, as described in the Plans for Reducing the Size of the Federal Reserve's Balance Sheet.

## C.3 Variables Description

Table 22: Description of the variables

Variables	Description	Ticker
UST yields 2-30y (%)	Interest rate paid on debt obligations issued by the United States Government.	USGG2YR
MBS yield (%)	Bloomberg US Mortgage-Backed-Securities index average yield-to-worst <sup>70</sup> .	LUMSTRUU
Term premium (%)	Adrian, Crump & Moench 10y Treasury term premium estimates. Analysis based on a five-sector, no-arbitrage term structure model.	ACMTP10
Global bond (USD)	Global aggregate total return index. Measure of the performance of the global investment grade, fixed-rate bond markets (government, corporate bonds from both developed and emerging markets issuers).	LEGATRUU
High-Yield (USD)	Global high yield total return index.	LG30TRUU
S&P 500 (USD)	Market-capitalization-weighted index of 500 leading publicly traded companies in the U.S.	SPX
S&P 500 Banks (USD)	The Index comprises stocks in the S&P Total Market Index that are classified in the GICS banks sector.	S5BANKX
S&P 500 Fut. (USD)	E-Mini S&P 500 Future Continuous Contract CME 3m.	ESA
Risk premium (USD)	S&P 500 Equity risk premium total return index. Measure of the spread of U.S. stocks over the returns of long-term Governments Bonds.	SPUSERPT
Dollar index (USD)	The dollar index tracks the relative value of the U.S. dollar against a basket of important world currencies.	DXY
Gold (USD/oz)	Gold price spot in USD (by ounce).	XAU
Oil Brent (USD/bbl)	Brent Crude Oil Continuous Contract (USD/bbl).	C01
CBOE VIX (%)	30-day option-implied volatility of S&P500 index returns; monthly average of daily data.	VIX
MOVE index (USD)	U.S. Treasury yield volatility implied by 1-month options on 2, 5, 10 and 30-year Treasuries.	MOVE
FRA-OIS Spread (%)	Difference between the U.S. dollar forward rate agreement (FRA) and an overnight index swap (OIS). It is a vanilla interest swap (Agreement between two counterparties to exchange cashflows (fixed vs. floating) in the same currency).	USFOSC1

OFR FSI (Index)	Daily market-based snapshot of stress in global financial market variables (yields spreads, valuation measures, interest rates).	RFSIUS
UST Liquidity (%)	U.S. Gov. securities liquidity index. Average yield deviation relative to a fitted yield curve across U.S. Treasuries with maturity beyond 1 year.	GVLQUSD
UST Bid-Ask (USD)	Difference between the highest price at which someone is willing to buy UST and the lowest price at which someone is willing to sell it.	USBIDASK
Fed fund futures (USD)	Financial futures contracts based on the federal funds rate and traded on the Chicago Mercantile Exchange	FF1
Eco surprises (index)	Citi economic surprises index, sum of the difference between official economic results and forecasts.	CESIUSD

Notes: All data are from Bloomberg.

## C.4 Robustness test (I)

Table 23: 3-days change in yields (in basis points)

	<b>UST 2y</b>	<b>UST 5y</b>	<b>UST 10y</b>	<b>UST 30y</b>	<b>MBS</b>	<b>Term Premium</b>
All QE Events	-3.66** (1.57)	-9.88*** (2.12)	-13.75*** (2.19)	-10.57*** (2.16)	-24.17*** (3.20)	-9.11** (4.38)
All Taper Events	3.56 (3.85)	13.73*** (5.18)	11.15** (5.35)	6.37 (5.29)	17.01** (7.82)	5.60 (10.71)
All QT Events	0.63 (1.93)	1.26 (2.59)	1.74 (2.67)	1.47 (2.65)	1.54 (3.91)	1.47 (5.36)

Table 24: 3-days change in asset prices (in %)

	<b>Global Bond</b>	<b>HY</b>	<b>S&amp;P500</b>	<b>S&amp;P500 Fut.</b>	<b>Risk Premium</b>
All QE Events	0.78*** (0.13)	-0.37* (0.19)	-0.14 (0.47)	-0.17 (0.48)	-1.53** (0.81)
All Taper Events	-0.92*** (0.32)	-0.65 (0.48)	-1.03 (1.16)	-1.01 (1.17)	0.38 (1.99)
All QT Events	-0.19 (0.16)	-0.34 (0.24)	-0.23 (0.58)	-0.19 (0.58)	-0.55 (0.99)

Table 25: 3-days change in asset prices (in %)

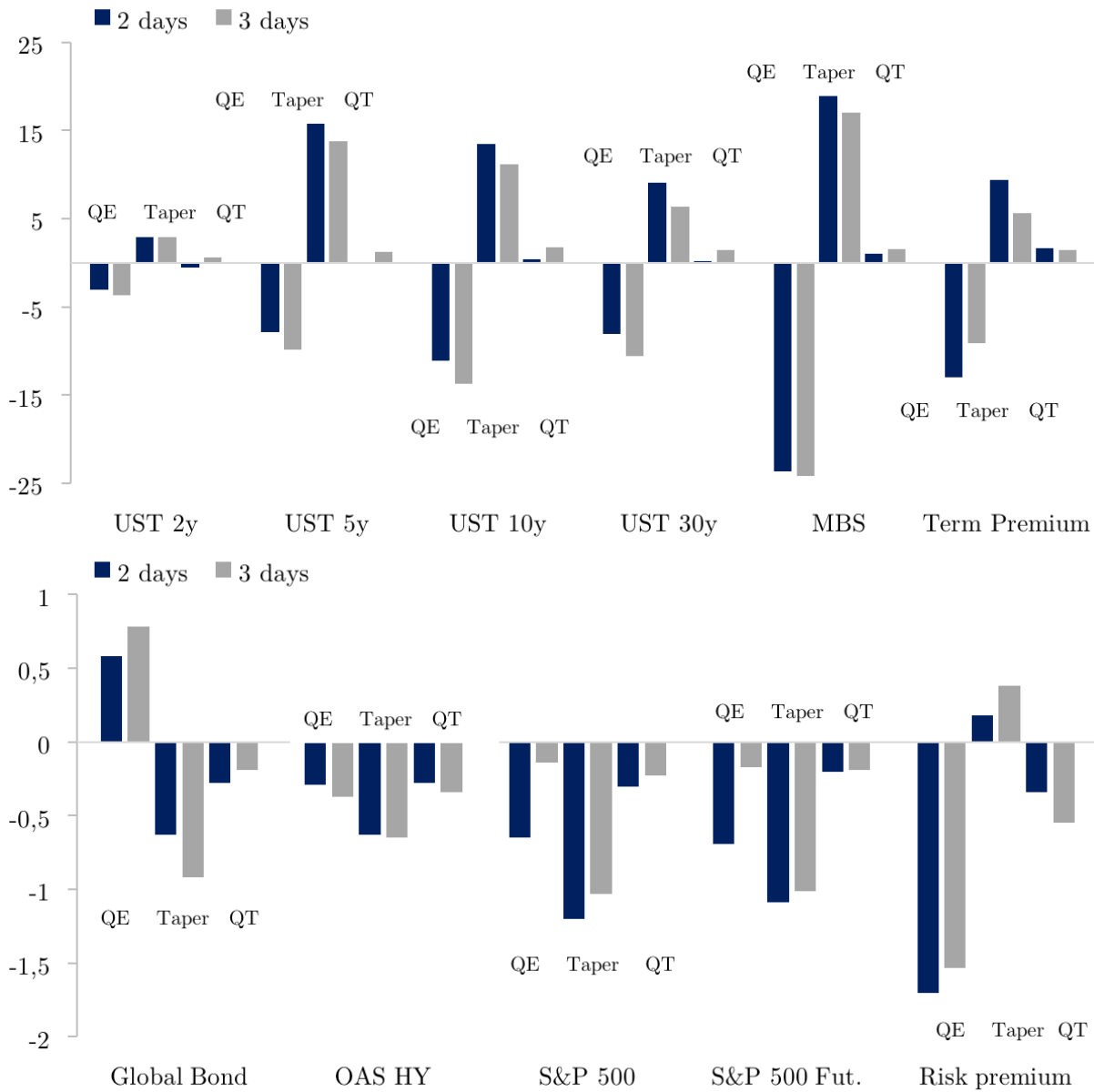
	<b>Dollar index</b>	<b>Gold</b>	<b>Oil Brent</b>	<b>CBOE VIX</b>	<b>MOVE index</b>
All QE Events	-0.67*** (0.19)	1.67*** (0.45)	-3.54** (1.73)	4.02 (3.14)	-5.73* (3.06)
All Taper Events	0.69 (0.48)	-3.57*** (1.10)	-1.42 (4.23)	5.41 (7.68)	11.55 (7.47)
All QT Events	0.13 (0.24)	-0.42 (0.55)	-1.40 (2.12)	-1.69 (3.84)	0.75 (3.74)

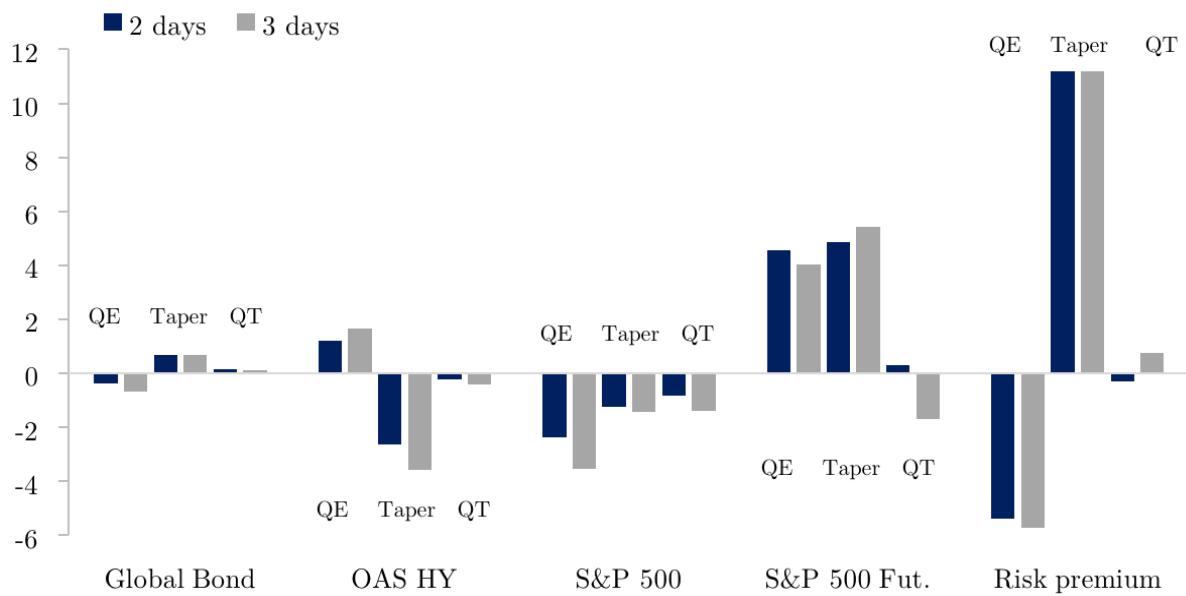
Notes: Coefficients  $\beta^{QE}$ ,  $\beta^{Taper}$  and  $\beta^{QT}$  from the regression:  $\Delta_{yt} = \beta^{QE} QE_t + \beta^{Taper} Taper_t + \beta^{QT} QT_t + \alpha_1 X_1 + \alpha_2 X_2 + \epsilon_t$ , where  $\Delta_{yt}$  is the two-day change in the yield or percent change in asset price and  $QE_t$ ,  $Taper_t$  and  $QT_t$  are dummy variables, which takes a value 1 on the dates that were related quantitative easing, tapering or quantitative tightening events.  $X_1$  and  $X_2$ , the control variables correspond respectively to economic surprises and Fed fund futures.

OLS standard errors are reported in parenthesis. Sample Period: November 2008 – May 2022. Observations: 3712.  
\*\*\* < 0.01, \*\* < 0.05, \* < 0.10.

## C.5 Robustness test (II)

Figure 46: QE, Tapering and QT Announcement Impact and Sensitivity to Window Size









## **Title: Central bank balance sheet and financial stability**

**Abstract:** We study the possible side effects of the prolonged use of central banks' balance sheet policies on financial stability, and the potential threats to financial stability from a reversal of these policies.

In the first chapter, we focus on the extent to which the financial stability has been affected by changes in central bank's balance sheet. We find that balance sheet policies support financial stability in the short and medium term and have no effect over the long term.

In the second chapter, we explore the differences in the effect of private assets purchases programmes from public ones. Our findings suggest that private asset purchase programs contribute more to financial system vulnerabilities than public ones, but the effects become insignificant in the longer run.

The third chapter investigates whether balance sheet's unwinding affect financial asset prices and financial stability metrics at the time of their announcements. We show strong asymmetries in the reaction of financial markets to balance sheet expansions, normalisation and unwinds. QT has no effect on asset prices, but negatively affect the liquidity of the US Treasury market.

**Keywords:** Monetary policy, balance sheet policies, financial stability, financial markets

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## **Title: Bilan des banques centrales et stabilité financière**

**Abstract:** Nous étudions les possibles effets indésirables de l'utilisation prolongée des politiques de bilan des banques centrales sur la stabilité financière, et les menaces potentielles qu'un renversement de ces politiques ferait peser sur la stabilité financière.

Le premier chapitre se concentre sur les effets des évolutions du bilan des banques centrales sur la stabilité financière. Dans le premier chapitre, nous nous concentrons sur la mesure dans laquelle la stabilité financière a été affectée par les changements de bilan des banques centrales entre 2008 et 2022. Nous constatons que les politiques de bilan soutiennent la stabilité financière à court et moyen terme et n'ont pas d'effet à long terme.

Dans le deuxième chapitre, nous étudions les différences entre les effets des programmes d'achats d'actifs privés et ceux d'actifs publics. Nos résultats suggèrent que les programmes d'achats d'actifs privés contribuent davantage à la vulnérabilité du système financier que les programmes d'achats d'actifs publics, mais que les effets deviennent insignifiants à long terme.

Le troisième chapitre étudie les effets de la politique de réduction du bilan de la Réserve fédérale sur les prix d'actifs et des indicateurs de stress financier. Nous mettons en exergue de fortes asymétries dans la réaction des marchés financiers aux expansions, normalisations et réductions du bilan. Les annonces relatives à la réduction du bilan n'ont pas d'effet sur les prix des actifs, mais affectent négativement la liquidité du marché du Trésor américain.

**Keywords:** Politique monétaire, politiques de bilan, stabilité financière, marchés financiers

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