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Unconventional monetary policies

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Date de soutenance / Data della discussione: 11/12/2012

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Acknowledgments

Many people have contributed to this dissertation in innumerable ways, and I am grateful to all of them. First and foremost, I would like to express my sincere gratitude to my supervisors, Prof. Pierpaolo Benigno and Mr. Henri Sterdyniak, for accepting to supervise my research in a joint PhD program and for their patience for all the administrative requirements and constraints that this framework imposed. Most of all however, I thank them for their continuous support and immense knowledge that were invaluable in all the time of research and writing of this thesis. I thank Prof. Benigno for the many opportunities he gave me. I will always be inspired by the values he transmitted to me through his work as a teacher and researcher. I would like to thank Mr. Sterdyniak for setting high requirements that motivated me to achieve more in this thesis than I thought I could. I also thank him for his perspicacity and teaching me to not to take everything that is generally accepted as true, for granted.

I am indebted to my supervisors as well as to Nicola Borri, Virginie Coudert, Francesco Giavazzi, Salvatore Nisticò and Philippe Weil who took their time to participate at the jury of the thesis defense.

I am grateful to my coauthor Marlène Isoré for sharing with me the DSGE adventure: our, often vivid, discussions made that work interesting and motivating. My thesis benefited greatly from comments and advice from: Agnès Benassy-Quéré, Nicola Borri, Gunther Capelle-Blancard, Benjamin Carton, Guillaume Daudin, Bruno Ducoudré, Refet Gürkaynak, Yukinobu Kitamura, Olena Havrylchyk, Paul Hubert, Philippe Martin, Salvatore Nisticò, Giuseppe Ragusa and Etsuro Shioji. I am also grateful to Esther Benbassat for her kindness and support, and to Claudine Lamaze for accompanying me from the very beginning of my studies at Sciences Po and for her professionalism and efficacy in organizing my thesis defense. I thank Giordano Otalli for his availability and help with several administrative issues.

This thesis has been partially supported by a fellowship “Bando Vinci

2009", granted from "French-Italian University", and I am thankful for their financial support.

I also acknowledge the financial support of LUISS Guido Carli. I am indebted to Hitotsubashi University, LUISS Guido Carli, OFCE and the Sciences Po Economic Department for providing stimulating research environment. I also thank the CEPII direction for assuring an excellent work environment that contributed greatly to my research in the final stage of the thesis. I also thank my colleagues in CEPII who made these last months much more enjoyable.

My special thanks go to my fellow PhD students in Hitotsubashi University, LUISS and Sciences Po, and especially to Daniela and Hermes with whom I spent long hours studying for the exams, Liza and Marlène who were my greatest support in the last months of the thesis, and Kaname and Taisuke who made my stay in Hitotsubashi a memorable adventure.

For the non-academic side of my thesis, I would like to thank my family and friends for their support, and more particularly to Marie, Yoshimi and Yumiko for always believing I would finish this thesis and reminding me that in the moments of doubts.

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Abstract

This thesis investigates the issues related to unconventional monetary policy implementation and is organized in four chapters. Chapter 1 compares unconventional measures in the United States (2007-2010) with the first big-scale unconventional experience in Japan (1999-2006). First, we discuss the way non-orthodox measures were implemented by the Fed and the Bank of Japan (BOJ) and we argue that the U.S. unconventional balance-sheet management was “asset-driven” whereas the Japanese more “liabilities-driven”. Second, we investigate the impact of non-standard measures on the private banks’ balance sheets, and in particular on lending to other banks, companies and households. The interbank lending slowed down in both countries but in the U.S. to much bigger extent. On the contrary, the lending to companies diminished more in Japan as there was double deleveraging process in firms and financial institutions. Third, we discuss the empirical evidence for the effectiveness of the Fed and BOJ unconventional monetary policies. In Japan “policy duration effect” contributed to lowering long-term yield, whereas in the U.S. the portfolio rebalancing effect proved more effective. Finally, we discuss risks connected to unconventional policies. While inflation does not seem to be immediate danger, the important credit risk on the Fed’s balance sheet brings up concerns about overstepping into fiscal policy and threatens the Fed’s independence. On the other hand, the reluctance of the BOJ to employ credit and quantitative easing more aggressively undermined its effectiveness in countering deleveraging pressures and deflation.

Chapter 2 evaluates empirically the impact of unconventional and conventional monetary policies in the United States on the Libor-OIS spread, long-term interest rates and long-term inflation expectations. To this purpose we investigate the behavior of selected asset yields on the days of monetary policy announcements. We find that liquidity facilities had weak impact on three-month Libor-OIS spread. The QE1 purchases of longer-term Treasury securities and agency

debt/MBS lowered nominal long-term interest rates. Furthermore, we find evidence that the Fed’s rescue operations and QE2 raised long-term inflation expectations. We also consider the impact of fiscal policy announcements. We find that the government bailouts reduced the three-month Libor-OIS spread while the fiscal stimulus announcements raised long-term inflation expectations.

Chapter 3 investigates the effect of the ECB unconventional monetary policies on banks’ and governments’ borrowing costs in the euro zone via event-based regression. Specifically, we measure the response of money market, covered bond and sovereign bond spreads on the days of monetary policy announcements. The results show that among ECB unconventional measures, long-term sovereign bond purchases (SMP) proved the most effective in lowering longer-term asset yields. The effects are the most important for the sovereign spreads in periphery euro-zone countries. The strong impact in the euro zone, exceeding the impact of similar measures in the U.S. and the U.K., suggests that the central bank intervention in sovereign market is particularly effective when the sovereign risk is important. The SMP also reduced the longer-term refinancing costs for banks as represented by covered bond spreads. Furthermore, covered bond purchase programs (CBPP 1 and 2) reduced covered bond spreads, sovereign bond spreads and to some extent the money market spreads. The 3-year LTRO announcement on the other hand was effective in reducing bank refinancing cost, via smaller money market spreads and covered bond spreads, but did not result in smaller government borrowing costs.

Chapter 4 incorporates a small and time-varying “disaster risk” à la Gourio (2012) in a New Keynesian model in order to account for increase in risk premia that motivated unconventional monetary interventions. In our model, a small change in the probability of disaster may affect macroeconomic quantities and asset prices. In particular, a higher disaster probability is sufficient to generate a recession without effective occurrence of the disaster. By accounting for monopolistic competition, price stickiness, and a Taylor-type rule, this paper provides a baseline framework of the dynamic interactions between the macroeconomic effects of rare events and nominal rigidity, particularly suitable for further analysis of conventional and unconventional monetary policy.

General Introduction

1. Monetary policy in unconventional times: transformation of the role of the central bank

The last five years have been a major challenge for the theory and practice of monetary policy. The Lehman Brothers collapse, on September 15, 2008, was followed by a dramatic increase in risk premia and a generalized panic on financial markets that spread from the United States to other parts of the world. As a result the interest rates on many assets increased and the credit in the economy became much less available. The central banks reacted to the increase in risk premia by lowering their main interest rates. Interest rate setting is known as conventional monetary policy and it proved effective in the past in influencing borrowing conditions. Therefore, in both economic theory and practice, the models in which the interest rate rule characterizes the monetary policy were commonly used by researchers (Woodford, 2003) and central bankers (Smets and Wouters, 2003).

However, since the beginning of the subprime crisis the transmission of central bank rates to other interest rates, which is a key channel of conventional monetary policy, has been severely impaired. The premia in interbank markets attained unseen level as the uncertainty about the banks' balance sheet health soared. In the United States, the mortgage and asset-backed security spreads increased while asset-backed commercial papers could hardly find acquirers. In Europe, the sovereign debt crisis has lead to large sovereign spreads and euro-zone financial market segmentation. As a result, huge disparities appeared in refinancing conditions for governments, banks and companies among the member countries despite the common monetary policy.

Another constraint faced by conventional monetary policy is a zero lower bound (ZLB) on nominal interest rates. This is already the case in the United States and in Japan where since December 2008 the target range for the policy rate has been set respectively between

0 and 0.25% and between 0 and 0.1% since. Furthermore, in the United Kingdom and in the euro-zone the target policy rates are set at historically low levels, respectively at 0.5% and 0.75%.

Some anecdotal experience from the past shows that there are times when monetary policy can and should do more than just setting the interest rates according to inflation target and output gap. The Hong Kong Monetary Authority made a very unconventional move during the Asian crisis, in October 1998. Hong Kong was in a currency board and the Authority was in a difficult position when the speculators were, at the same time, selling the local currency and short-selling the Hong Kong stocks. If the Authority, as speculators expected, played its conventional monetary policy card and raised interest rate to defend the currency, the value of the stocks would go down, making the short-sales of stock very profitable. However, the HK Monetary Authority managed to deter speculators by directly purchasing the stocks in order to increase their price. This unconventional monetary policy allowed the HK Monetary Authority to foil the self-fulfilling speculative attack and support the economy without having to give up its primary objective of exchange-rate target.

The Hong Kong example shows that there are situations where conventional monetary policy cannot respond to challenges set by financial markets and economic environment. However, it was in Japan between 1999 and 2006 when unconventional monetary policies were implemented at the large scale on regular basis. After the housing and asset bubble collapse, the banks' balance sheets were of poor quality because of the accumulated non-performing loans. The sharp rise in risk premia led to banking crisis in 1997-1998. The double deleveraging process in banking sector and companies that followed was accompanied by the economic stagnation. The Bank of Japan (BOJ) decreased its target policy rates to zero in April 1999 but real interest rates remained positive as deflation and deflationary expectations persisted. Faced with the ZLB constraint the BOJ at first committed to keeping the interest rates at zero level until the deflationary tensions are dispelled. Furthermore, it implemented the Quantitative Monetary Easing Policy (QMEP) in March 2001 together with stronger commitment on keeping the zero interest rates. The QMEP consisted in setting the target for the excess reserves that commercial banks held

at the BOJ. The increase in reserves was obtained thanks to long-term government bond purchases and short-term lending to banks. More generally, the BOJ unconventional monetary policies can be categorized according to Bernanke and Reinhart (2004) into three groups:

- Expectation management strategy. Central bank commitment can affect the expectations of the future interest rates and therefore the long-term interest rates.
- Changes in the composition of the central bank balance sheet by purchasing unconventional (risky) assets (credit easing).
- Expansion of monetary base by providing banks with excess reserves at the central bank (quantitative easing).

The deflation period in Japan and the BOJ non-orthodox measures were perceived as an isolated experiment that was irrelevant for the conduct of monetary policy in other developed countries. And yet, since the subprime crisis outburst in 2007 the central banks around the world have implemented some kind of unconventional monetary policy and their innovative policies have by far exceeded the Japanese measures.

Even though unconventional monetary policies can be classified into three categories described above, in practice each country designed its own “unconventional policy toolkit” depending on the country economic situation and the central bank operational constraints. We first recall the majors unconventional policies carried out by the Federal Reserve (Fed), the Bank of England (BOE) and the European Central Bank (ECB).

As soon as the first signs of the subprime crisis were publicly known, in August 2007, the Federal Reserve made an unusual commitment of providing reserves as necessary through open market operations to promote trading in the federal funds market at rates close to its target rates. Furthermore, it reduced the spread between the primary credit rate (discount rate) and the target federal funds rate to 50 basis points and began to allow the provision of primary credit for terms as long as 30 days. As using discount window was considered by banks as sending a bad signal about their financial stending, the Fed has implemented in December 2012 a special liquidity facility designed to lend to depository institutions: Term Auction Facility (TAF). Under

this program Fed auctioned collateralized loans of 28 and 84 days. At the same time it initiated currency swap agreements (swap lines) with other central banks (BOE, ECB and BOJ among others). Under these arrangements the Fed provided dollars to other central banks for use in their jurisdictions. After the collapse of Bear Stearns, the Fed announced two lending facilities for primary dealers: Term Security Lending Facility (TSLF) providing term loans of Treasury securities, and the Primary Dealer Credit Facility (PDCF) providing discount window loans. The failure of Lehman Brothers was followed by creation in September 2008 of the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF) designed to support money market funds and the market for ABCP. In October 2008, the Fed established the Money Market Investor Funding Facility (MMIFF) designed to provide liquidity to US money market investors, and the Commercial Paper Funding Facility (CPFF) providing a liquidity backstop to US issuers of commercial paper. Finally, in March 2009 in cooperation with the Treasury the Fed launched the Term Asset-Backed Securities Loan Facility (TALF) intended to revive the market for ABS.

In addition to temporary liquidity and lending facilities for specific financial sectors that are now all terminated, the Fed purchased important quantities of longer-term Treasury bonds and Agency¹ bonds and mortgage-backed securities (MBS). In November 2008 the Fed announced purchases of Agency debt and MBS (overall final amount reached \$1450 bln) and in March 2009 purchases of longer-term Treasury bonds (\$300 bln). These purchases are called a first round of quantitative easing (QE1). The second round was announced in November 2010 and consisted in purchasing only Treasury securities (\$600 bln). Furthermore in September 2011, the Fed implemented the Maturity Extension Program (MEP, also called “Twist Operation”) that involved selling \$400 billion in short-term Treasuries in exchange for the same amount of longer-term bonds (amount increased in June 2012 by \$267 bln). In September the third round of quantitative easing (QE3) was decided and concerned purchases of MBS (\$40 bln per month). The particularity of the third round was that the end of the program was not announced and the Fed committed to continue them

¹Namely Fannie Mae and Freddie Mac, whose principal activity consisted in expanding the secondary market in mortgages. They were effectively nationalized in September 2008.

“if the outlook for the labor market does not improve substantially”.²

Finally, the Fed used expectation management strategy to reduce longer-term interest rates when the target fed funds were reduced practically to zero in December 2008. More precisely it promised to keep exceptionally low levels of the federal funds rate for some time. This commitment was subsequently reinforced and in September 2012 the Fed stated that the economic conditions are likely to warrant exceptionally low levels of the federal funds rate at least through mid-2015. In this way, the Fed communicated to markets its commitment to lower the path for future interest rates and hence reduce long-term interest rates.

In the United Kingdom, the BOE also enhanced liquidity provisions, supported dysfunctional financial markets and implemented large-scale asset purchases. Unlike the Fed however, it did not commit to keep future short-term interest rates at exceptionally low levels. In April 2008, it introduced Special Liquidity Scheme (SLS) allowing banks to exchange illiquid mortgage-backed securities for Treasury Bills with the maturity up to three years. After the Lehman Brothers collapse, the BOE increased longer-term repos substantially from around £12 bln before the crisis to £180 bln in early 2009 (Cross et al., 2010). It also started providing liquidity in dollars thanks to currency swaps with the Fed (September 2008). Furthermore, the BOJ introduced in Autumn 2008 a Discount Window Facility (DWL) to allow banks borrowing government bonds, for 30 or 364 days, against a wide range of collateral. The Discount Window Facility was designed to remain in place as a permanent feature of the BOE monetary policy, but the Special Liquidity Scheme ended in January 2012. As in case of the Fed’s TSLF, the security swaps programs introduced by the BOE (SLS and DWL) did not appear on the BOE’s balance sheet.

Initially, the expansion of the BOE’s balance sheet was due to increase in fine-tuning operations and longer-term reverse repo operations. However, as the target policy rate was decreased to 0.5%, the BOE initiated in March 2009 the Asset Purchase Facility (APF) intended to boost nominal demand growth and to ensure meeting the 2% inflation target in the medium term. The APF enabled the BOE to

²FOMC statement of September 13, 2012.

purchase UK government securities in the secondary market and high-quality private sector assets, including commercial paper and corporate bonds. The first round of purchases was set at £200 billion worth of assets, mostly UK Government debt. The program was further increased with additional purchases of £75 billion in October 2011 and in February 2012 the Committee decided to buy an additional £50 bln. In July 2012 the BOE announced the purchase of a further £50 bln to bring total assets purchases to £375bln.

At the beginning of the subprime crisis, the European Central Bank as other central bank increased significantly liquidity provisions to banks via additional fine-tuning operations, more important main refinancing operations and supplementary 3-month longer-term operations (LTROs). In Autumn 2008, the ECB intensified further liquidity-providing operations by reducing the corridor of its standing facilities, implementing fixed-rate full-allotment procedure (FRFA) and lengthening the maturity of LTROs. The FRFA procedure was an exceptional measure allowing banks to satisfy all their liquidity needs at fixed rate (MRO rate) in all operations in euro and in foreign currency conducted by the ECB. The maturity of LTROs were initially increased from three months to one year during the global crisis but the adverse development of the euro-zone debt crisis made the ECB propose to banks in December and February 2012 the three-year loans (3Y LTRO).

The ECB also proceeded to outright purchase of assets. In May 2009 the first covered-bonds purchase program started (€60 bln), followed by second program in October 2011 (€40 bln). Covered bonds were important source of bank longer-term financing and the ECB intended to diminish the banks' borrowing cost and also ease the strains on interbank market. The ECB was the last of the three central banks to start sovereign bonds purchases. In May 2010, it introduced Securities Markets Programme (SMP) designed to purchase longer-term sovereign bonds amid the euro-zone debt crisis. In September 2012 it announced creation of Outright Monetary Translations (OMT) in order to buy short-term government securities.

While all these banks expanded their balance sheet significantly in the recent years, and therefore experienced quantitative easing, the assets they accumulated differ importantly. The United States where the fi-

nancing of the economy passes to the greatest extent through financial markets, it seemed important that the central bank support directly these market segments that were the most disrupted: mortgage markets, CP, ABCP, and ABS. As a result, the claims to private sector on the Fed balance represent around 30%. In the euro zone on the other hand, two-thirds of the external financing of firm is allowed by banks. The claims on banks represent therefore the major part of the ECB claims.

The approach to sovereign debt purchases is another difference among the central banks. While the claims on public sector represent a major part of the Fed claims and the quasi totality of the BOE claims, it constitutes much smaller part of the ECB assets. The particular operational framework of the ECB makes it difficult to proceed to sovereign debt purchases. In fact, the euro zone is constituted of 17 countries and the purchases of a debt of a particular country can be politically difficult to accept, especially if this means a wealth transfer from one country to another.

The central bank communication associated with government bonds purchases seems also important for this measure's effectiveness. With this respect, the ECB had different approach to the Fed. While the latter precisely described its quantitative easing modalities, the ECB remained unclear about the amounts of the debt purchased and the duration of the first sovereign debt program (Securities Markets Programme, SMP). The purchases stopped and resumed with no clear guidelines. Even though the ECB is independent in its actions, it seems clear that the fierce opposition to bond purchases in Germany had an impact on the design of the program. The conditionality attached to the second sovereign bond purchases (Outright Monetary Transactions, OMT) is also a result of the particular euro-zone construction. The ECB can only intervene if the country accepts the structural reforms and budget consolidation. With this respect, the ECB exceeds its traditional role as it *de facto* facilitates governments financing but also indirectly imposes on them the economic reforms.

The ECB case is not isolated. All central banks implementing unconventional monetary policy see their roles transformed whether it is intended or not. Even though the critics warn against the dangers of increasing and modifying the central bank balance sheet, the

central banks continue to implement unconventional measures.³ It seems important to investigate these new central bank functions as the ZLB constraint is likely to be present for a long time⁴ and the unconventional monetary policies may soon consolidate their position and become a new standard.

The new roles of central banks are linked to sudden increase in aggregate uncertainty: market participants are unwilling to lend funds and start hoarding liquidity for precautionary reasons. The central banks can use unconventional monetary policies to diminish the amount of risk held by private agents in several ways.

First of all, they exercise their lender of last resort (LLR) function and provide the funds to illiquid banks. In these operations the monetary authority takes over the liquidity risk by accepting illiquid assets in return for central bank money or other liquid assets. During the crisis all central banks provided ample amounts of liquidity in form of excess reserves or government bonds⁵ in exchange for less liquid assets. However, the particularity of the recent five years is that the central banks practically substituted themselves for the interbank market. The Fed extended significantly the number of counterparties eligible to its liquidity facilities, the ECB provided banks with unlimited liquidity at fixed rate (Fixed-rate full-allotment procedure). As the first chapter of this thesis shows in detail, the availability of the cheap central bank money while the uncertainty concerning the counterparty risk is high, can limit the incentive to participate in interbank market which in turn becomes less liquid.

According to Bagehot (1873)'s conception of the lender of last resort, the lending should be made "on all good banking securities" and more largely "on every kind of current security, or every sort on which money is ordinarily and usually lent". With this respect the central banks exceeded the conventional conception of the LLR as they enlarged eligible collateral for their lending operations and also directly purchased unconventional risky assets. In other words, the central banks took on their balance sheet the credit risk that the pri-

³ECB announced unlimited sovereign bonds buying program (OMT) on September 6, 2012; Federal Reserve announced mortgage-backed securities purchases (Quantitative Easing 3) on September 13, 2012; Bank of Japan increased the total size of its Asset Purchase Program by 10 trillion of yen (14% increase).

⁴On September 13, the Federal Reserve announced that it would keep the target policy rate in a range 0-0.25% at least through mid-2015.

⁵The Fed lent government bonds through Term Securities Lending Facility (TSLF).

vate agents did not want to hold. The Fed for instance exposed its balance sheet to important amounts of MBS, ABS and the assets of AIG and Bear Sterns, the ECB distributed unlimited three-year loans to banks and the Bank of Japan and the Bank of England purchased commercial papers and corporate bonds. The central bank purchases of risky assets and accepting them as collateral aimed at reducing the private cost of credit risk.

Furthermore, the purchases of longer-term government debt, conducted by four central banks mentioned above to different extent, diminished sovereign risk held by private agents. Additional consequence of longer-term government bonds purchases is that they helped the government to increase the borrowing without having to face higher interest rates. This is true, especially in the United States, the United Kingdom and Japan where the long-term interest rates remain at a very low level (respectively around 1.7%, 1,7% and 0,8%) even though the governments increased substantially their debt. The central bank role in financing governments is a controversial one, and the monetary authorities never stated it as their objective.

New balance sheet management and new functions of the central banks during the crisis may have important consequences on the behavior of market participants that are yet difficult to evaluate. The malfunctioning of the interbank market seems permanent now which raises important questions concerning the future of that market and the impact on the overall health of the banking system. Indeed, an easy access to funding and little collateral requirements can make the weak banks with insufficient capital dependent on the central bank's liquidity. The funding can therefore contribute to maintain "alive" insolvent banks which would not start lending to the companies and households even with additional liquidity. This argument was often made with respect to BOJ accused of artificially maintaining "zombie" banks and in this way postponing the recovery. During the Japanese crisis the important provision of liquidity had indeed no impact on aggregate lending. Only once the disposal of bad loans and recapitalization of the banks took place the banks started lending again. Therefore, the central bank liquidity relives banks with funding difficulties but also lessens the pressure on banks to reform.

Another important issue is linked to the credit risk that the central

banks accepted on their balance sheet. As the central banks' profits are transferred *in fine* to the Treasury, the taxpayers are directly impacted by the monetary policy decisions. The central banks protected themselves by imposing important haircuts on accepted collateral and purchased assets. However, these assets are intended to be kept at the central banks for a long time. As long as the economy recovers as planned, they will make profit on these assets. If however another shock hits the economy and the existing problems are not solved, the central bank could bear losses and face the dilemma whether to ask the government for rescue (recapitalization, lending of sovereign bonds) or just monetize the loss. Both of these outcomes seem undesirable. Monetizing of losses threatens credibility of the central bank and can cause inflation. On the other hand, covering the losses by the government brings up the risk of overstepping into fiscal policies. Traditionally, the central bank would buy securities at the same prices as other financial market participant would buy them. Since the recent crisis however, the central banks purchased the assets that were unattractive to private agents and arbitrarily decided which market participants would benefit from its lending operations.

Finally, the critics mention the inflation threat as a consequence of unconventional measures. However, the impact of unconventional monetary policies on inflation is more complex. First, it is not certain from empirical and theoretical point of view that such an effect would appear. Second, if inflation is a potential danger, it can be at the same time a beneficiary effect in deflationary environment. We treat this question in more detail in the first and second chapter of this thesis.

The new roles that the central banks endorsed are vividly criticized by some researchers and policy-makers and strongly encouraged by others. The theoretical models currently used by central bankers do not take into account financial markets disruptions, uncertainty and the role of the central bank in this environment even though the literature that takes these features into account is growing rapidly (Adrian and Song Shin, 2010; Cúrdia and Woodford, 2011; Gertler and Karadi, 2011).

In the next section, we review the transmission channels, according to existing theory, through which the unconventional monetary policies might work. We present transmission channels for: (I) Expectation

management; (II) Expansion of monetary base; (III) Changes in the composition of the central bank balance sheet. Additionally, we discuss “financial stability channel”.

2. Unconventional monetary policies transmission channels

A) Expectations management

When the nominal short-term interest rate is close to zero the monetary policy can still stimulate the aggregate demand by affecting the entire expected future path of short real rates. The central bank can announce that it will keep the policy rates at exceptionally low levels or alternatively that it will tolerate more inflation in the future. In fact, according to New Keynesian models (Eggertsson and Woodford, 2003) current demand depends not only on the current interest rate but also on the future expected short-term rates and expected inflation. This relationship is expressed by a consumption Euler equation, derived from the maximization problem of a representative household (IS curve):

$$Y_t = E_t \{Y_{t+1}\} - \sigma [i_t - E_t \{\pi_{t+1}\} - r_t^n]$$

where Y_t is the deviation of output from its natural level, i_t is the short-term nominal interest rate, π_t is inflation, E_t is an expectation operator and r_t^n is a natural rate of interest following an exogenous shock process.

The above equation IS can be reiterated in a following way:

$$Y_t = -\sigma E_t \left\{ \sum_{0 \leq k \leq \infty} (i_{t+k} - E_{t+k} \{\pi_{t+k+1}\} - r_{t+k}^n) \right\}$$

where $E_t \{\sum_{0 \leq k \leq \infty} (i_{t+k} - E_{t+k} \{\pi_{t+k+1}\})\}$ can be considered as a real long-term interest rate. Long-term real interest rates are the crucial transmission mechanism of monetary policy and have an important effect on durable goods expenditures and business investment. Moreover, from the finance perspective, long-term rates are fundamental determinants of mortgage prices, derivatives and other long-term financial assets. Therefore, the monetary policy can still be effective at zero lower bound and spur the aggregate demand by making a credible commitment about the expected path for future interest rates and future inflation. The central bank should commit to set the interest rates at the lower level than the Taylor rule might call once the economy

starts to recover. The Fed implemented this strategy since it lowered its policy rates to 0-0.25% range. An alternative to committing to lower interest in the future, nominal GDP target path, was proposed by Romer (2010) and Woodford (2012). According to this proposition the Fed would pledge to maintain the funds rate target at its lower bound as long as nominal GDP remains below a deterministic target path. This strategy equals to tolerating higher inflation in the future until the nominal GDP target is met.

Nevertheless, expectation management strategy suffers from intertemporal credibility problem as the Fed has an incentive to raise interest rates when the economy recovers. The market participants expect the Fed to give up on its promise when the inflation increases and, as a result, do not change their expectations. The central bank has however additional tool to make its commitment more credible: monetary base expansion via longer-term assets purchasing. In this context, raising interest rates would automatically diminish the value of the central bank assets and even create losses. This “signaling channel” of monetary base expansion will be discussed in the subsection C) of this Introduction.

B) Changes in the composition of the central bank balance sheet (Credit easing)

Another tool at the disposal of the central bank when the interest rates are close to zero is to purchase, or accept as collateral, assets that are not traditionally accepted by the central bank. Indeed, in normal times the central bank sets the short-term rates close to the target rate via open market operations in which it buys or sells government securities (usually short-term). In a period of financial distress however, it can modify the composition of its assets by purchasing the securities that suffer from temporary liquidity problems or are undervalued by the financial markets. The effectiveness of this policy is based on the “portfolio balance effect”. The theoretical basis of the open-market purchases of non-standard assets were set by Eggertsson and Woodford (2003). Their representative agent model predicts no effect for such operations on price level or output. However, this result holds only under following assumptions: (1) the assets being bought and sold are valued only for their pecuniary returns, and (2) all investors can purchase and sell unlimited quantities of these assets.

These assumptions are likely not to hold during crisis, especially the latter, as there exist binding constraints on participation in particular markets. One example of general equilibrium analysis in which these constraints exist and credit easing affects asset prices is Càrdia and Woodford (2011). As for the first assumption, Krishnamurthy and Vissing-Jorgensen (2011) show that US government debt possesses non-pecuniary qualities that are valued by the financial sector above their pure pecuniary returns as the Treasuries are often required as collateral in repo transactions. Furthermore, replacing a representative agent with no preference between markets and assets by heterogeneous agents can also provide rationale for central bank asset purchasing. The recent model of Vayanos and Vila (2009) based on preferred habitats of investors provides a theoretical basis for the portfolio rebalancing effect in case of long-term government bond purchases. In their model, the interest rates of all maturities are determined through the interaction between risk-averse arbitrageurs and investor clienteles with preferences for specific maturities. In this framework the central bank purchases of long-term Treasuries can lower the long-term yields because they shorten the average maturity of government debt and therefore the duration risk held by market participants.

Changing the composition of the central bank balance sheet can take several forms depending on the central bank objective and its operational constraints. First, the central bank can buy or accept as collateral specific assets that it considers as particularly touched by the crisis and at the same time important to the economy. In doing so it intends to increase their prices and as a result the wealth of economic agents. The Fed supported MBS, ABS, commercial papers and asset-backed commercial papers for example while the ECB bought covered bonds and the BOE corporate bonds and commercial papers. While delivering private agents from the risk linked to these assets, the central bank accumulated it on its own balance sheet.

Longer-term liquidity providing operations are also a part of central bank balance sheet composition change. Traditionally, the loans to banks are of maximum three-month maturity. This maturity was extended by many central banks and reached 3 years in case of the ECB longer-term refinancing operations (LTROs). The interbank market was not functioning anymore and the central bank wanted to give to

banks insurance of obtaining the longer-term funding they need. As a consequence, the ECB took on its balance sheet the risk of such longer-term lending, including eventual default of borrowing banks and maintaining insolvent banks operational.

Accumulation of public debt on central bank balance sheet is another form of credit easing. The central bank purchases of government bonds can affect their prices via portfolio rebalancing effect mentioned earlier but also by diminishing the risk of sovereign default. This second channel was particularly important in the euro-zone as some member countries lost access to market refinancing. Monetary policy cannot in principle guarantee public debt. However, the sovereign debt crisis showed that when agents are pricing in the supposed default of a given country, it can lead to self-fulfilling bad equilibrium outcome and large purchases of public debt can prevent it. Even though the specific European stability facilities were created (EFSF/ESM), only the central bank can commit to unlimited purchases of the debt.

“Pure” credit easing would consist of purchasing risky assets while selling safe assets that the central banks held already on its balance sheet. An example of this policy is given by “Twist Operation” conducted by the Fed since September 2011 which consists in buying long-term government securities while selling short-term Treasury bills. However, in most of the cases, the purchases of risky assets or accepting them as a collateral entail monetary base increase. Table 1.2 of the Chapter 1 presents schematically the difference between pure quantitative and qualitative easing.

C) Monetary base expansion (Quantitative easing)

Expansion of monetary base is also a controversial policy from a theoretical point of view. Traditionally, the reduced-form quantitative theory of money argued that increase in money supply will result in higher inflation. However, this theory requires that the velocity of money is constant over time which is not empirically verified. Also, this theory refers to the supply of money and not monetary base. New monetarists underline for instance that according to Divisia M3 and M4 monetary indices the money supply in the U.S. today is no higher than in early 2008.

The old Keynesian literature (Keynes (1936) and Hicks (1937)) emphasized on the other hand that increasing money supply when the

policy rate is close to zero would not have effect on either output or prices. Additional money provided by the central bank is not used to purchase securities as the agents expect the interest rate to increase and the prices of securities to fall. Therefore they are in a “liquidity trap” and hold money instead. New Keynesian theories, such as Eggertsson and Woodford (2003) and Woodford (2012), confirm the ineffectiveness of monetary base expansion in a general equilibrium framework. They claim that at the zero lower bound quantitative easing cannot stimulate the output nor raise the prices. As in case of credit easing, when financial frictions are present and liquidity of assets is affected, quantitative easing may be non-neutral. In particular, increase in money supply could reduce the liquidity premium and therefore reduce long-term interest rates (Andres et al., 2004) and stimulate investment (Kiyotaki and Moore, 2012).

In addition to the quantity effect (portfolio rebalancing) which affects risk premium, there exist another channel which has an impact on private sector’s expectations of the future monetary policy. This transmission channel is called “signaling effect”. Important expansion of the central bank’s balance sheet often requires purchasing long-term Treasury bonds or other risky assets that the central bank plans to keep on its balance sheet for an extended period of time. Raising interest rates would expose the central bank to capital losses on the assets it holds. Therefore important increases of monetary base can be associated by financial markets with a signal that the monetary easing will continue longer than previously expected. In this respect, managing expectations about the future money supply is more important than the current money supply. For instance, committing to permanent increases in monetary base could increase private sector’s inflation expectations (Auerbach and Obstfeld, 2005). Credible commitment about permanent monetary expansion makes agents expect that the interest rates will remain low even when the zero lower bound does not bind anymore, especially if it conducted via risky asset purchases.

The link between monetary base expansion and inflation is therefore not straightforward. The experience of the central banks that increased substantially their balance sheet, BOJ between 2001 and 2006 among others, has not provided evidence of inflation expecta-

tions unanchoring. The main risk linked to monetary base expansion seem to be the important amount of risky assets that the central bank accepted on its balance sheet (See Chapter 1).

D) Supporting financial stability

The additional channel through which the three types of unconventional monetary policies described above could affect the economy is by stabilizing the financial system. In a 2008-2009 financial crisis the overall functioning of the financial system was impaired due to the malfunctioning of interbank money markets. Increased risk and liquidity premia on large segments of financial market froze the credit channel of the monetary policy. Various unconventional monetary policies were designed to encourage the flow of credit to firms and households and thus contribute to minimizing the economic downturn. Indeed, the central bank can have stabilizing effects on financial markets by making credible commitment about maintaining target rates at very low level for a long time, by injecting liquidity to the system and supporting specific segments of money and credit markets. These measures may be effective in stabilizing the system for several reasons. First, they relieve the liquidity constraints of financial institutions and therefore reduce the incentive to sell their assets to meet their own refinancing needs. They also reduce the banks' uncertainty with respect to funding liquidity of other market participants and therefore diminish counterparty risk premia. Finally, the additional funding source from the central bank should decrease the demand for banks to excessively hoard liquidity for precautionary reasons. The liquidity constraints of financial institutions have negative impact on their lending capabilities and may result in credit crunch. The central bank unconventional measures by ensuring funding liquidity can diminish these adverse effects.

3. Objective and organization of the thesis

Unconventional monetary policies are relatively recent phenomenon and there are vivid debates on theoretical and empirical level aiming to establish which policies and under what conditions are desirable. This thesis makes a contribution to this debate and its objective is twofold. First, we intend to bring new evidence on the effectiveness of unconventional measures and contribute to their better understanding (Chapters 1, 2 and 3). Furthermore, we build a theoretical frame-

work that accounts for a disaster probability perceived by investors, a particular feature that prepares the background for unconventional monetary policy intervention (Chapter 4).

The first chapter of the thesis highlights the multiple ways of unconventional monetary policy implementation and the importance of choosing appropriate measures according to country-specific problems. More precisely, it compares recent unconventional measures in the United States (2007-2010) with the first big-scale unconventional experience in Japan (1999-2006). Both central banks implemented three types of unconventional monetary policy: expectation management, monetary base expansion and purchases of risky assets. We argue however that the U.S. unconventional balance-sheet management was “asset-driven” whereas the Japanese more “liabilities-driven”. While the BOJ intended to increase the excess reserves to banks so that they expand their lending, the Fed intervened directly in financial markets they wanted to support. We investigate the impact of non-standard measures on the private banks’ balance sheets, and in particular on lending to other banks, companies and households. The interbank lending slowed down in both countries but in the U.S. to much bigger extent. On the contrary, the lending to companies diminished more in Japan as there was double deleveraging process in firms and financial institutions. Furthermore, we discuss the empirical evidence for the effectiveness of unconventional monetary policies in Japan and in the U.S. It appears that in Japan “expectation management strategy” contributed to lowering long-term yield, whereas in the U.S. the sovereign bond purchases proved more effective (portfolio rebalancing effect). The different effect of non-orthodox tools in Japan and in the U.S. can be attributed to overall strategies of the central banks: the Fed purchased aggressively risky assets while the BOJ intended to provide large amounts of excess reserves to banks without taking too much risk. Finally, we discuss risks connected to unconventional policies. While inflation does not seem to be immediate danger, the important credit risk on the Fed’s balance sheet brings up concerns about overstepping into fiscal policy and threatens the Fed’s independence. On the other hand, the reluctance of the BOJ to employ credit and quantitative easing more aggressively undermined its effectiveness in countering deleveraging pressures and deflation.

Chapters 2 and 3 evaluate, via econometric techniques, the effectiveness of unconventional monetary policies in the United States and in the euro zone. Chapter 2 measures the impact of unconventional and conventional monetary policies in the U.S. on the Libor-OIS spread, long-term interest rates and long-term inflation expectations. To this purpose we investigate the behavior of selected asset yields on the days of monetary policy announcements. We find that liquidity facilities other than TAF reduced the three-month Libor-OIS spread. The QE1 purchases of longer-term Treasury securities and agency debt/MBS lowered nominal long-term interest rates. Furthermore, we find evidence that the Fed's rescue operations and QE2 raised long-term inflation expectations. We also consider the impact of fiscal policy announcements. We find that the government bailouts reduced the three-month Libor-OIS spread while the fiscal stimulus announcements raised long-term inflation expectations.

Chapter 3 assesses the impact of the ECB unconventional monetary policies on banks' and governments' borrowing conditions in the euro zone via event-based regression. The market borrowing conditions for banks are represented by the changes in money market spreads and covered bonds spreads while the sovereign bonds spreads reflect the euro-zone government borrowing costs. The results show that among ECB unconventional measures, the two sovereign bonds purchasing programs (SMP and OMT) proved the most effective in lowering longer-term asset yields. The effects are the most important for the sovereign spreads in the Southern European and range from 35 basis points (Italy) to 476 basis points (Greece) in case of SMP. As a comparison, the U.S. and U.K. sovereign spreads also fell following the quantitative easing implemented by the Fed and the Bank of England but the magnitude of the effect was much smaller: 5 and 9 basis points respectively. The strong impact in the euro zone suggests that the central bank intervention in sovereign market is particularly effective when the sovereign risk is important. The SMP had also the strongest impact on covered bonds spreads. Furthermore, covered bonds purchases programs reduced covered bond spreads, sovereign bond spreads and to some extent the money market spreads. The 3-year LTRO announcement on the other hand succeeded in reducing bank refinancing conditions but was ineffective in diminishing govern-

ment borrowing costs.

In the fourth chapter we initiate a theoretical work that reproduces important feature of recent crisis: a sudden increase in disaster risk that generates a recession, a fall in inflation, a flight to quality in terms of asset demand, depresses investment and labor, as well as lowers consumption. More precisely, we incorporate a small and time-varying “disaster risk” à la Gourio (2012) in a New Keynesian model. A small change in the probability of disaster may affect macroeconomic quantities and asset prices. In particular, a higher disaster probability is sufficient to generate increase in risk premium and leads to recession without effective occurrence of the disaster. By accounting for monopolistic competition, price stickiness, and a Taylor-type rule, this chapter provides a baseline framework of the dynamic interactions between the macroeconomic effects of rare events and nominal rigidity, particularly suitable for further analysis of monetary policy. This theoretic set-up allows taking into account particularities of the 2007-2010 crisis, namely the agents’ perception of risk. This particular feature of the crisis was the rationale for the unconventional central bank intervention, policy rates being close to zero and ineffective. We also set up our next research agenda aimed at assessing the desirability of several unconventional policy measures in case of a variation in the probability of rare events.

1 Unconventional monetary policies in the United States (2007-2010) in the light of the Japanese experience (1999-2006)¹

1.1 Introduction

Since the beginning of the subprime crisis, the Federal Reserve (Fed) reacted very promptly to turbulence on financial markets by changing its usual monetary policy. The implemented unconventional monetary policies can be regrouped into three categories²: i) expectation management, ii) central bank balance sheet expansion and iii) changing the composition of the central bank balance sheet. The first consisted in credibly committing to lower future short-term interest in the future, and therefore reduce long-term interest rates. The second type of policy consist in increasing the monetary base and provide banks with excess reserves in order to stimulate asset prices increase and lending to economy. Finally, the third strategy requires purchasing or accepting as collateral unconventional, risky assets in order to affect their yields and prices.

These policies were previously carried out in Japan between 1999 and 2006 during the deflation period. However, the intensity and modalities of these unconventional measures were different in the United States and in Japan as the two countries have different economic and financial structures. Moreover, the Fed could use the Japanese experience to better design their unconventional monetary policy toolkit.³ While evaluating the effectiveness of unconventional monetary policies, it seems particularly important to take into consideration country-specific factors as well as the intensity with which each unconventional tool was employed.

¹I would like to thank my supervisors Pierpaolo Benigno and Henri Sterdyniak for their guidance and valuable advice. I am also grateful to Agnès Benassy-Quéré for helpful comments and suggestions. Any errors are mine.

²For the details of these policies and their theoretical transmission channels see General Introduction (Section 2) of this thesis.

³President of the Fed, Ben Bernanke, before joining the Fed carried out research on Japanese unconventional monetary policies (Bernanke and Reinhart (2004); Bernanke et al. (2004)).

This paper compares the non-standard measures implemented by the Fed during the recent financial crisis with the first large-scale unconventional monetary experience in Japan from 1999 to 2006, with a particular focus on the balance sheet management in both countries. The analysis of the Japanese experience seems interesting as the Fed used a wide range of tools that were previously employed by the BOJ. There are many concerns concerning their effectiveness and the time past since these measures were wound up in Japan allows necessary perspective to analyze their effects.

First, we argue that the U.S. unconventional balance-sheet management was “asset-driven” whereas the Japanese more “liabilities-driven”. Different balance sheet management reflects different underlying economic problems in the U.S. and Japan (bad security vs bad loan issue) and different expected results (lowering specific asset prices vs fighting deflation). Accordingly, the Fed’s exit strategy is more challenging than the BOJ’s exit and requires additional tools.

Second, we investigate the impact of non-standard measures on the private banks’ balance sheets, and in particular on lending to other banks, companies and households. The interbank lending slowed down in both countries but in the U.S. to much bigger extent. On the contrary, the lending to companies diminished more in Japan as there was double deleveraging process in firms and financial institutions.

Finally, we discuss the empirical results of unconventional policies in the United states and in Japan. The money market disruption being much more important in the U.S., the empirical evidence on the impact of non-standard measures on interbank lending rates is much more available for the U.S. market. The effectiveness of liquidity measures in reducing money market spreads is overall rather weak. This results, joint with the evidence from commercial banks balance sheets, support our argument that money markets are less relevant as the Fed substituted itself for the interbank market.

The impact of unconventional measures on long-term interest rates is not the same in the United States and in Japan. As Fed government purchases were implemented on much larger scale, they succeeded in reducing long-term interest rates via “portfolio rebalancing” channel. In Japan on the other hand, the long-term interest rates were diminished via “expectation management” channel.

While inflation does not seem to be immediate danger, the important credit risk on the Fed's balance sheet brings up concerns about overstepping into fiscal policy and threatens the Fed's independence. On the other hand, the reluctance of the BOJ to employ credit and quantitative easing more aggressively undermined its effectiveness in countering deleveraging pressures and deflation.

The remainder of this paper is organized as follows. The following section presents the way unconventional monetary policies were implemented in the U.S. and in Japan, with particular focus on balance sheet management. Section 1.3 analyzes the impact of non-standard measures on private banks balance sheets. Section 1.4 reviews empirical evidence on effectiveness of the non-standard measures on long-term interest rates, money market rates and inflation expectations. In section 1.5 we discuss risks linked to unconventional balance sheet management. Section 1.6 concludes.

1.2 Implementation of unconventional monetary policies in the United States and Japan

1.2.1 Unconventional monetary policies implemented in the United States and Japan

Bank of Japan (1999-2006)

The Bank of Japan was the first to implement unconventional monetary policies during the prolonged stagnation following the burst of the asset price bubble in the early 1990s. During that period, it also faced some serious deflationary pressures for about a decade. Negative inflation rates measured by the consumer price index (CPI) change first appeared in 1998 and lasted until the autumn 2005. To counteract the deflationary pressure, the Bank of Japan (BOJ) adopted various unconventional policies. First, in 1995, it lowered the target of the uncollateralized overnight call rate from 1.75 percent to 0.5 percent. Second, it decided to encourage the uncollateralized call rate to be at about zero percent in February 1999. This was the introduction of the so-called "zero interest rate policy (ZIRP)". Afterward, at the BOJ governor's press conference in April 1999, the BOJ committed to continue ZIRP "until deflationary concerns were dispelled". Third, in March 2001 the BOJ adopted "quantitative monetary easing policy

(QMEP)" with a large expansion of the monetary base. In doing so, the BOJ had also made a stronger commitment to maintain this policy package until the core CPI inflation rate registered zero percent or higher on a sustainable basis.⁴ The QMEP framework included employing by the BOJ the outstanding current account balances (CABs)⁵ as an operating target for monetary market operations. In addition, it was also declared that the BOJ was ready to increase the purchase of long-term government bonds if necessary to provide ample liquidity. The BOJ also proceeded to purchases of other risky assets: purchased asset-backed securities (from July 2003 to March 2006) and stocks held by commercial banks (from October 2002 to September 2003). The QMEP was exited in March 2006 when the conditions for the exit had been satisfied, i.e. both the development of actual inflation rate and outlook of inflation rate were above zero percent.

Federal Reserve (2007-2011)

During the 2007-2010 crisis, other central banks also used alternative monetary tools. The generalized uncertainty regarding the healthiness of bank balance sheets generated frictions in the financial and monetary markets. In that context, lowering the central bank interest rates did not affect the interbank rates to the extent it used to do. As a consequence, monetary policy remained unable to lower the cost of credit. The Federal Reserve responded to this problem in a number of ways. First of all, it introduced new liquidity facilities. It also expanded the maturities and range of eligible collateral, the frequency of operations and the number of counter-parties. As the crisis got worse, especially after the failure of Lehman Brothers, the unconventional monetary policies were implemented even more intensively. The Fed started its interventions in specific market segments and initiated the asset purchase programs including commercial papers, agency debt and MBS as well as longer-term government debt. The Fed also conceded swap lines to other central banks to enable them to provide further dollar liquidity. Figure 1.1 illustrates the way the unconventional policies affected the Fed's balance sheet. Since the beginning of the crisis the composition of the Fed's assets was significantly altered and the size of the balance sheet more than doubled. In addition to the balance

⁴The commitment was further specified in October 2003.

⁵Current account balances (CABs) are the reserves that the commercial banks keep at the BOJ.

sheet management policy, the Fed committed to keeping the interest rates at “exceptionally low levels for an extended period of time”. This commitment was subsequently reinforced as Fed stated that the economic conditions are likely to warrant exceptionally low levels of the federal funds rate at least through mid-2015.⁶

1.2.2 From Japanese Quantitative Easing to the U.S. Credit Easing

Expectations management, credit easing and quantitative easing were implemented both by the Fed and by the BOJ (Table 1.1). However, there were important differences in the implementation of the policies, especially as far as balance sheet management is concerned. Unconventional balance sheet management can depart from its conventional structure (Table 1.2a) and can take form of the changes in the composition of the balance sheet (Table 1.2b), balance sheet expansion (Table 1.2c), or the mix of both (Table 1.2d). The President of the Fed, Ben Bernanke, in his speech on January 13, 2009 (Bernanke, 2009) stressed the differences between the BOJ and the Fed’s balance sheet management approach. While implementing the quantitative easing the BOJ focused on the liability side of the balance sheet and therefore set the excess reserves targets to attain. The Fed on the other hand put attention on the asset side of the balance sheet and on its composition in particular. The core of the crisis in the Fed’s point of view was a credit crisis and the fact that increased uncertainty discouraged private lenders from lending to each other. In addition, securitization of certain assets was a particular characteristic of the subprime crisis. Once the crisis started the general uncertainty about the quality of several segments of the financial market made the private agents reluctant to buy these financial instruments. As a result the Fed concentrated on the types of assets it wanted to support substituting itself as a main “market maker”. This “credit easing” approach is particularly well reflected on the Fed’s balance sheet in the first stage of the crisis. The Fed wanted to improve the market functioning by introducing new lending facilities (see Table 1.3 for the description of the programs) and lending to banking and non-banking institutions. Figure 1.2b shows that between August 2007 - September 2008 the asset side of the Fed’s balance sheet changed its composition, while

⁶The FOMC decision of September 13, 2012.

the composition of liabilities remained the same. These balance sheet developments are an illustration of the “pure credit easing” as they did not lead to the balance sheet expansion. After the Lehman Brothers collapse, the Fed’s balance sheet started to inflate (Figure 1.2c). The expansion was due to the large-scale purchases of mortgage-backed securities and agency and Treasury debt (Quantitative easing 1), followed by another important Treasury debt purchases (Quantitative easing 2). Even though the Fed did not set the target for excess reserves as the BOJ did in Japan between 2001-2006, the excess reserves increased dramatically. During this period of the crisis the Fed implemented a mix of credit and quantitative easing. While changing the composition of its assets by increasing holding of unconventional assets such as long-term Treasury bonds, MBS and the loans to rescued financial institutions (AIG, Bear Stearns etc.), the Fed also increased the size of the balance sheet.

The BOJ also implemented a mix of credit and quantitative easing but focused mainly on the liability side. There is a difference between these two approaches even though they are not mutually exclusive. By focusing principally on the composition of the asset side, the Fed positioned itself as a “market maker of last resort” and in fact substituted itself for private financial intermediation. On the other hand, the liability management and in particular the increase in excess reserves is a way to provide the banks with the buffer for funding liquidity risk. There was also an intended effect on investor’s portfolio rebalancing: the excess reserves were supposed to be used by banks to purchase riskier assets and distribute credit, eventually leading to inflation increase. Therefore, in Japan the asset side composition changed mainly as a result of increases in targeted current account balances on the liability side. The BOJ explicitly considered the purchases of the long-term JGBs as a part of its QMEP and as a mean to attain its CAB target. On the contrary, in the United States, the liability side followed the asset side expansion at the Fed. The U.S. monetary authority decided to acquire specific financial assets and as a consequence of these purchases it credited the private banks accounts at the Fed (excess reserves increased). Unlike the BOJ they did not mention that these purchases would increase the money supply which would in turn have a positive effect on the economy. The effect of these operations on

the economy was not supposed to come from changing the supply of banks reserves but by changing the quantity of risky assets held by the Fed.

The different approach to unconventional balance sheet management can be partly explained by the differences in the source of the economic crisis in Japan and in the United States. In both countries the housing bubble preceded the crisis and the bubble burst had an adverse impact on the activity of financial institutions that used to lend to property-related businesses. Even though the non-performing loans were a problem in both countries, the specificity of the crisis that hit the U.S. was that the mortgage loans were securitized and there was an increased uncertainty about the health of financial institutions holding these securitized assets. Therefore, the Japanese crisis was more linked to a “bad loan problem” whereas the financial crisis in the U.S. to a “bad security problem”. Given that the initial bad-security problem was enhanced by the lack of transparency on the quality of these instruments after the crisis started, the counterparty risk increased as a consequence and the Fed’s intervention in particular segments of market seems justified. Another explanation for the different weight attributed to purchasing targeted assets (credit easing) rather than simply providing excess liquidity (quantitative easing) is linked to the different primary objective of the Bank of Japan and the Fed during the crisis. The former intended principally to fight deflation whereas the latter had an objective of financial stability, even though the deflation concern was also present in the United States. Finally, the possible rationale for the Fed to intervene directly and aggressively on credit markets and Treasury and agency bonds market was that it doubted that the simple monetary base increase could be enough to stimulate the economy.⁷

In the next section we will describe in more details balance sheet management in Japan and in the United States.

1.2.3 Balance sheet management in the US

Asset management

The is no unique choice of the unconventional assets that the central bank can buy or accept as a collateral as part of its unconventional

⁷The empirical evidence shows that monetary expansion in Japan was not successful (see section 1.4).

monetary policy. The choice depends on the nature of the shock hitting the economy and on the economy's financial structure. In the beginning of the subprime crisis the general uncertainty about banks' liquidity and solvency made banks reluctant to lend to each other. The interest rates on interbank markets historically followed very closely the Fed's target rate but since August 2007 the spread between interbank rate (Libor) and expectations of future policy rate (OIS) widened significantly (Figure 1.3a). To counter the tensions on the interbank market the Fed launched the Term Auction Facility (TAF) program designed to lend to depositary institutions. Given that primary dealers are important part of the U.S. financial system, after the bankruptcy of Bear Sterns the Fed introduced two facilities providing primary dealer with discount window loans (PDCF) and Treasury securities in exchange for the risky assets (TSLF).

As the crisis worsened after the collapse of Lehman Brothers, the markets for several debt instruments were severely damaged making it difficult for the financial and non-financial institutions to refinance themselves. The commercial paper and asset-backed commercial paper markets were particularly disrupted. The Fed introduced new funding facilities to diminish the spreads on these markets (Figure 1.3b and Figure 1.3c). Finally, in March 2009 in cooperation with the Treasury the Fed launched the Term Asset-Backed Securities Loan Facility (TALF) intended to revive the market for ABS. In 2009 the Fed started purchasing longer-term Treasury debt as well as the Agency debt and mortgage-backed securities (QE1). By changing the demand for these assets the Fed intended to lower their yields. In 2010 the purchases of the longer-term Treasury debt resumed. All these operations contributed to the change of the composition and the size of the Fed's balance sheet. Whereas the liquidity facilities were temporary and are not any longer present on the Fed's balance sheet, the large amount of MBS, longer-term Agency and Treasury debt and credit to financial institutions (AIG, Bear Sterns) are still part of the Fed's assets.

Liability management

Before the crisis, the liability side of the Fed's balance sheet is mostly composed of the currency in circulation (Figure 1.2a). In the first stage of the crisis, the Fed sterilized the purchases of unconventional

assets by selling its holdings of short and medium-term Treasury securities. Unlike the asset side, the composition of the liability side remained unchanged during this period (Figure 1.2b). Nevertheless, after the Lehman Brothers collapse the sterilization operations could not cover the supplementary liquidity and lending programs launched by the Fed and its balance sheet started to expand (Figure 1.2c). Initially, the increasing volumes of Fed's assets were accompanied by increasing the Treasury account at the Fed.⁸ This approach could not last as the Treasury could not issue debt without limits. Therefore, in order to increase its lending and asset purchases, the Fed started to credit the commercial banks' accounts at the Fed with the excess reserves.

In normal times, increase in amounts of excess reserves would have immediately lowered overnight federal funds rates and stimulated aggregate lending. Figure 1.3 shows that the average overnight rate stays indeed often below the target rate during the crisis period but this decline is very small compared to liquidity injected. Indeed, as we will discuss in the next section, the uncertainty concerning the financial health of financial institutions made the banks hold most of their excess reserves idle at the Fed rather than lending them out. Given the possibility that once the economy recovers, the banks should be willing to use their funds to make new loans the Fed introduced measures that would encourage banks to keep their reserves at the central bank. First of all, it decided to pay an interest on excess reserves. Figure 1.3 shows the impact of the announcements about the interest rates payments on the effective overnight Fed Funds rate and the spread between the effective rate and the target which became negative. Announcements about raising interest paid on excess reserves seem to make deposits at the Fed more attractive and as a result increase the effective overnight rate.⁹

The Term Deposit Facility introduced in May 2010 was another tool

⁸In practice, this cooperation between Treasury and the Fed can be seen as two simultaneous operations: purchase of the risky asset from commercial bank by the Fed and the purchase of the government security from the Treasury by the commercial bank. More specifically, the Fed buys unconventional assets from a commercial bank and increases its account at the Fed. At the same time, Treasury sells a Treasury securities to the commercial bank. The commercial bank's account at the Fed is reduced and the money is transferred to the Treasury account at the Fed. As a result, the Treasury account at the Fed increases while the excess reserves of a commercial bank remains unchanged.

⁹Nevertheless, the effective rate is still lower than the target rate even when the interest rates on excess reserves equals the target rate. This can be explained by the fact that not all interbank participants have accounts at the Fed. Additionally, the arbitrage is made unprofitable when the interest rates are close to zero as the banks have to pay the fees when withdrawing funds from the Fed.

designed to encourage the banks to keep the reserves at the Fed. Term deposits are interest-rate bearing instruments with maturity of 84 days or less. This facility allows the Fed to lock up funds for longer time. Interest on reserves and term deposit accounts give commercial banks incentive to keep their newly created reserves at the Fed. By implementing these measures the Fed attains two goals. First, it can continue to manage the asset side according to its objectives, i.e. purchase targeted assets and lend to specific segments of financial markets, which require expanded balance sheet. Second, it sends signal to the markets that the Fed has tools to prevent the excess reserves to be transformed into credit and eventually create inflation. However, this approach has some potential drawbacks. It makes the Fed become the major actor of the interbank market as the banks prefer to keep the funds at the central bank rather than to lend to each other or to companies and households. Also, it supposes that the Fed has a better understanding than financial markets of what assets should be purchased.

This analysis of the balance sheet management of the Fed shows that it focused indeed on credit easing and intended the changes in relative asset supplies to reduce liquidity and risk premia in dysfunctional markets. This approach differs from that adopted by the Bank of Japan which concentrated on the liabilities side management.

1.2.4 Balance sheet management in the Japan

Liability management

When the BOJ started quantitative monetary easing policy (QMEP) on March 19, 2001 it switched its main operating target from the uncollateralized overnight interest rate to the outstanding balances of current account balances (CABs). The target was at first fixed at ¥5 trillion and then raised several times to ¥30-35 trillion (the required reserves amounted to ¥4 trillion). Indeed, the excess reserves that commercial banks held at the BOJ increased in previously unseen pace (Figure 1.4). As a consequence the money market rates went virtually to zero (Figure 1.5).

The BOJ did not pay the commercial banks interests on excess reserves as its goal was to encourage banks to expand lending. In March 2006 the BOJ terminated QMEP and announced that the CABs would be

reduced within seven months according to the money market conditions. The winding down of the quantitative easing was successful and did not create interbank money market tensions.

Asset management

To meet the CABs target the BOJ proceeded to outright purchases of long-term Japanese Government Bonds (JGBs). These purchases accounted for the highest percentage of assets acquired in exchange for the Current account balances at the BOJ (Figure 1.4 B). These purchases gradually increased to match the CABs target to attain to 1.2 trillion yen in May 2004. In the pursuit of QMEP, the BOJ had also implemented longer-dated intervention in the money market, in particular it extended the maximum maturity for outright purchases of bank bills and purchases of JGSs with repurchase agreements to up to one year. In fact, given the negative real interest rate it was difficult to find borrowers willing to pay positive interest rate at short maturities. Therefore, to meet the CABs target the BOJ had to lengthen the maturity of outright purchases of bills (the lending maturities) from the three-month operations in 2001 to 11-month in 2005 and also expand the range of counterparties in these operations (Maeda et al., 2005). The purchases of bank bills was an important part of short-term liquidity provisions and played an important role in the BOJ exit strategy.

Apart from changes in asset composition induced by QMEP, the BOJ also implemented the credit easing strategy to reduce risk and liquidity premia on selected markets. These operations were executed on a much smaller scale compared to purchases of JGBs (Figure 1.4) and were linked to non-performing loans of financial institutions. Faced with the credit crunch of 1998 the BOJ decided to take commercial paper (CP) as a collateral in repo operations. As the NPL problem reappeared in late 2002, the BOJ purchased subsequently the stocks held by commercial banks from October 2002 to September 2003. Additionally, from July 2003 to March 2006 it also purchased asset-backed securities (ABS) and asset-backed commercial paper (ABCP) as it wanted to improve the transmission of monetary policy to credit markets. Given the importance of the banking system in the financing of the Japanese economy, most credit easing measures, with the exception of limited ABS purchases, were designed to address the problems

of the banks.

1.2.5 Exit strategies

During the troubled times the excess reserves that banks hold at the central bank do not transform into lending and they do not constitute an inflationary threat. Once the economy recovers, the central banks have several tools at their disposal to prevent the banks from using the injected liquidity to distribute credit to economy. First, they can encourage private banks to keep funds at the central bank by paying interest on excess reserves or proposing term-deposits to private banks. They can also issue central bank debt or, depending on the monetary framework, they can raise the interest rate for the emergency loans (discount rate in the United States or Basic Discount rate in Japan).

However the exit strategy from unconventional balance sheet management requires the size and composition of the balance sheet to get back to normal. This can be achieved via traditional reverse repurchase agreements or outright sales of conventional and unconventional assets. Moreover, the central banks can let some assets mature and not reinvest the proceeds which naturally diminishes their balance sheet size. Given the significant differences in balance sheet management, the exit strategy seems much more challenging for the Fed than to Bank of Japan.

1.2.5.1 Japan

The Bank of Japan announced the exit from the QMELP on March 9, 2006 indicating clearly that the reduction of the excess reserves amount would be conducted through adjustments of its liquidity operations and not by a immediate reduction of its holdings of Japanese government securities.¹⁰ The BOJ did not want to proceed to large-scale sales of long-term JGBs in order to preserve their value and prevent long-term interest rates increase. The portfolio of long-term bonds would decline naturally as some of the securities mature. In-

¹⁰The BOJ announcement on March 9, 2006: “The outstanding balance of current accounts at the Bank of Japan will be reduced towards a level in line with required reserves. . . . the reduction in current account balance is expected to be carried out over a period of a few months, taking full account of conditions in the short-term money market. The process will be managed through short-term money market operations. With respect to the outright purchases of long-term interest-bearing Japanese government bonds, purchases will continue at the current amounts and frequency for some time.”

stead, the BOJ decided to reduce the amount of excess reserves by adjusting short-term liquidity provisions. In particular it stopped rolling over the short-term bank bills acquired during QMEP as a complement for its long-term JGB purchases. As a consequence both excess reserves and banks bills on the BOJ balance sheet diminished very quickly without disturbing financial and money markets (Figure 1.6). In fact, this exit strategy worked well and the interbank market got back to its normal functioning. This was a necessary condition for the BOJ to change its official targets from CABs to overnight uncollateralized interest rate as the call money market was affected by the crisis (Figure 1.14).

1.2.5.2 The United States

The balance sheet expanded much more in the United States than in Japan. The Fed also purchased incomparably bigger amounts of longer-term government bonds and held on its balance sheet huge quantities of unconventional assets including mortgage-backed securities. Therefore, the Japanese way of exiting unconventional policies does not seem possible for the Fed. In fact, the exit in case of the United States seems to be a multi-stage process and the Fed's President, Ben Bernanke, communicated extensively on the options that the Fed had at its disposal (Bernanke, 2010b). First of all, some liquidity and credit facilities were designed to be attractive only in troubled times as the pricing of accepted assets included important haircuts. Therefore, some of these facilities expired smoothly as the economic conditions improved and the private agents could get better borrowing conditions on the financial markets. Furthermore, the loans had the duration of three months or less and the Fed had a possibility to simply let them expire just as BOJ did. Indeed, the Fed managed to wind up all liquidity facilities in the beginning of 2010.¹¹

However, there are other assets of much longer maturity that the Fed took on its balance sheet. In particular, the Fed extended credit to Maiden Lane LLC and Maiden Lane II LLC following the rescue of Bear Stearns and AIG. These assets are likely to remain on the Fed's balance sheet for a long time as their liquidity and value are not well defined. In addition, the Fed acquired important quantities of longer-

¹¹The last liquidity facility, TALF expired on June 30, 2010.

term Treasury and agency securities. Also, as some of these long-term securities matured (MBS), the Fed decided to reinvest them in longer-term Treasury bonds. In September 2011, the Fed decided to implement the maturity extension program, under which it would sell \$400 billion of shorter-term Treasury securities and buy longer-term Treasury securities. In September 2012 additional MBS purchases were announced (QE3). Given these circumstances, any large scale selling operation of longer-term Treasury or MBS is likely to raise the yields of these assets.

Given the balance sheet structure of the Fed, it seems more probable that it gives incentives for the banks to keep their reserves at the central bank rather than proceeds to the proper exit strategy any time soon.

1.3 Impact on commercial banks' balance sheet

The ultimate objective of most of unconventional measures implemented in Japan and in the United States was to stimulate lending to companies and households. However, the increase in the monetary base did not trigger higher credit increase as Figure 1.7 illustrates. In order to get some preliminary evidence on the effectiveness of unconventional monetary policies, it is useful to analyze in more details the evolution of the private banks' balance sheets.

1.3.1 Impact on commercial banks' balance sheet in the United States

In the United States, aggregate lending and in particular loans and leases (real estate loans, commercial and industrial loans) slowed down at the beginning of 2008 and started to decline at the end of 2008 as shown on Figure 1.8.¹²

The commercial banks' holdings of securities continued to increase but its composition changed after the start of the crisis. Since the beginning of 2008 holdings of government securities increased reflecting the "flight to quality". On the other hand, holdings of more risky assets declined Figure 1.9.

¹²Intermediate increase is due to inclusion of off-balance assets of the banks.

The most visible impact of unconventional monetary policies can be noticed on the interbank loans. Since September 2008 the interbank loans have rapidly declined. The sudden decrease of interbank lending in September 2008 was partly offset in December 2008 as the Fed announced several new easing measures.¹³ Nevertheless, the interbank lending started to decline again a few months later (Figure 1.10a)

Figure 1.10b shows the cash assets of the bank and interbank lending. The amount of cash assets, which includes the deposits at the Fed, increased dramatically while the interbank lending was slowing down. Commercial banks preferred to keep their funds at the Fed rather than lend them in the interbank market. It appears that the unconventional monetary policy measures led to *de facto* substitution of the Fed for the interbank market.

This phenomenon can be further noticed when comparing fed funds loans and reverse repos with banks and non-banks which do not have access to the central bank excess reserves (Figure 1.10c). Indeed, the fed funds and reverse repos to non-banking institutions (i.e. brokers and dealers) started to increase in October 2009, while the similar loans to banks continued to decline. The volumes of these loans accorded to non-banks are now much higher than those allowed to banks. In the past, it was generally the case that the loans to non-banks were smaller.

The analysis of the commercial banks' balance sheets suggests that since the beginning of the crisis the Fed progressively took a role of the interbank intermediation. The volumes exchanged on the interbank market declined significantly as the commercial banks had sufficient liquidity at the Fed and did not have to borrow funds from other banks. When the economy showed signs of recovery, commercial banks started to lend these funds to non-banks which did not have access to central bank liquidity. The substitution of the Fed for the interbank market is an important feature of this crisis. The dramatic increase in the spread between the interbank rate (LIBOR) and the expectations of future Fed Funds rate (OIS) can be seen in a different light given this evidence. Indeed, this spread seems less relevant given that the banks were financing themselves directly at the Fed. Moreover, the

¹³On December 16th announced the new target policy rate between 0 and 0,25% and made a commitment to maintain fed funds at exceptionally low levels for some time. The Fed also repeated its intention to buy agency debt and MBS and eventually to expand these purchases. The FOMC also announced that they were evaluating the benefits from purchasing longer-term Treasury securities.

smaller trading volumes might have contributed to the increase of the spread. Therefore, unconventional measures can have two opposite effects: they reduce the spread it as they diminish liquidity and credit risk, but they also increase it by reducing trading volumes and leaving on this market the institutions that do not have direct access to central bank money. From this point of view, measuring effectiveness of Fed's liquidity facilities according to decline in interbank spreads is not sufficient. This may explain the lack of consensus in empirical literature on the effectiveness of new liquidity facilities (see Section 1.4).

1.3.2 Impact on commercial banks' balance sheet in Japan

After the burst of a bubble in Japan in the beginning of the 1990s the traditional transmission channels of monetary policy, and in particular the credit channel, did not function correctly. Bank lending remained stagnant and started to decline rapidly since the banking crisis in 1997-1998 (Figure 1.11).

The quantitative easing and the current account balances (CABs) at the BOJ were intended to be used for lending. The concerns regarding financial institutions' standing led to tensions in money and credit markets and increased the risk and liquidity premia. To the extent that the banks were liquidity constrained, ample liquidity provisions by the central banks accompanied by the commitment to continue these provisions should have had positive impact on bank lending. However, these huge amounts of funds were not transformed into loans. After asset and real estate bubble collapse, firms were facing the dramatic asset prices decrease and had to start deleveraging in order to restore the health of their balance sheets and improve their credit ratings. At the same time, the banks which lent to these firms had to declare increasing volumes of non-performing loans and restrained their lending. This double balance-sheet adjustment from both firms and banks produced downward pressure on the economy. Moreover, banks reduced their holdings of Japanese stocks and increased their holdings of safe assets (government bonds) and more profitable foreign assets (Figure 1.12) worsening further the positions of the Japanese firms.

In these conditions, unconventional monetary policies, zero interest rate policy (ZIRP) and quantitative monetary easing policy (QMEP),

were not able to stimulate lending and investment. Even though interest rates were close to zero since 1995 and the excess reserves were freely available to banks, both demand and supply of credit were blocked. Bank lending started to recover in 2005 when the non performing loans (NPL) issue was finally resolved¹⁴ and the corporate demand for funds started to grow. Bowman et al. (2011) present empirical evidence that the expansion of reserves likely boosted the flow of credit. However, this effect is small and only valid in the initial years of QMELP when the banking system was very weak. Finally, it was partly offset as at the same time banks reduced their lending to each other.

Indeed, Figure 1.13 shows that the increasing deposits at the BOJ were accompanied by a decline in deposits held at other commercial banks. When QMELP ended in 2006 the deposits in other banks rose significantly. There were several incentives for the commercial banks to keep their deposits at the BOJ rather than in other banks. The banks were not certain about their counterparty's balance sheet standing and the perceived default risk was high. Moreover, they were required by the Bank of International Settlements (BIS) to hold capital for their deposits at other commercial banks whereas the deposits at the central bank did not require any capital provision.

Moreover, in Japan as in the United States but to a smaller extent, the large increase in excess reserves diminished the activity in Japanese interbank market (call market). The institutions turned to the BOJ for funding, especially for longer-term and uncollateralized loans (Figure 1.14). However, after the initial decline, the interbank outstanding amounts started rising again in 2003 for collateralized loans, and in 2004 for uncollateralized loans.

The reduced interbank activity was at first due to the failures of several important security houses between 1997 and 1998 (for example Sanyo Securities and Yamaichi Securities). Their defaults on claims in the uncollateralised call money market led lenders in the interbank market to reevaluate the credit risk. The volatility of the overnight rates in the uncollateralised call money market increased and the volumes lent declined, reflecting higher credit risk premia. The subsequent nationalization of several banks which had become insolvent

¹⁴Takenaka plan 2002-2003.

increased the risk premia even more. Even though several recapitalization programs were initiated between 1997-2001, they were not big enough and they did not force banks to make correct evaluation of their underestimated NPL. New minister in charge of Financial Services Agency, Heizo Takenaka, proceeded to more rigorous evaluation of banks' assets in September 2002. The Takenaka plan increased the regulatory pressure and led to a important change in loan classifications by the banks in 2002 which increased the volume of NPL declared by the banks (Figure 1.15). Following Takenaka's reform, the number of NPL decreased and the banks started to rebuild their capital. Increased capital of the banks encouraged them to lend to firms and the aggregate lending went up in the beginning of 2006.

Even though QMEP contributed to lower interbank lending activity, this decline was much smaller than in the U.S. and did not last for a long time. In fact, once the NPL problem was resolved in 2003 banks started to lend to each other again even though they still had the possibility to finance themselves at the BOJ directly. The substitution of central bank liquidity for interbank liquidity was much shorter and less pronounced than in the U.S.

The comparison of the impact of unconventional monetary policies in Japan and in the United States confirms that the important amounts of excess reserves are not sufficient to encourage banks to supply loans. Their willingness to extend lending is determined more by the quality of their own and other banks' balance sheet, the perceived liquidity and counterparty risk and the demand for loans from companies and households. It is however interesting to notice that the deleveraging process and decline in lending was much smaller in the U.S. where credit easing operations were done on a much larger scale.

1.4 Empirical evidence of the effectiveness of unconventional monetary policies in Japan and in the United States

This section reviews the evidence on the effectiveness of the unconventional monetary policies implemented in the United States during the 2007-2010 crisis and in Japan between 1999-2006. We focus on the effectiveness of unconventional policies in relieving the strains on money markets, lowering long-term interest rates and raising inflation

expectations.

1.4.1 Impact on money market spreads

Several unconventional monetary policy tools were designed to reduce the tensions on interbank markets and improve the transmission channels of monetary policy. In the United States, the tensions on interbank market appeared in August 2007 and intensified after the collapse of Lehman Brothers. Indeed, the generalized uncertainty concerning the health of banks' balance sheets made the banks unwilling to lend to each other. In particular, the Libor-OIS spread which is considered as a barometer of interbank market distress widened significantly.¹⁵ To address this issue, the Fed implemented new liquidity facilities.

There is a discussion in the recent literature concerning the effects of new liquidity facilities on the Libor-OIS spread. Taylor and Williams (2009a) claim the liquidity facilities like TAF (Term Auction Facility) cannot have an impact on the Libor-OIS spread because its widening is mostly due to credit risk and not liquidity risk. On the other hand, Wu (2011) claims that the spread was caused by the misallocation of liquidity and that the financial strains in the interbank money market were alleviated after TAF was implemented. Aït-Sahalia et al. (2010) consider all macroeconomic and financial sector policy announcements in the United States, the United Kingdom, the euro area and Japan and find that both macroeconomic and financial sector policy announcements were associated with reductions in the Libor-OIS spreads. Szczerbowicz (2011) considers the impact of all policy announcements in the United States but takes a different approach: regression-based event study, which allows to estimate the effect of all policies simultaneously. She finds that announcements related to TAF do not affect the Libor-OIS spread. The news related to other liquidity facilities (TSLF, PDCF, AMLF, CPFF, MMIF, AMLF) reduced the spread but the overall impact is quite weak.

As discussed earlier, the lack of strong evidence confirming the effectiveness of unconventional measures on interbank spreads can be attributed to unconventional monetary policies themselves. The ex-

¹⁵The London interbank offered rate (Libor), is an average interbank borrowing rate published daily by the British Bankers' Association (BBA). The overnight-indexed swap (OIS) rate represents market expectations of the funds rate over the future months. There is no exchange of principal and only the net difference in interest rates is paid at maturity, so there is very little default risk in the OIS market.

cess reserves freely available at the Fed reduced the incentive for the banks to lend to each other and the volumes exchanged on the market declined, possibly increasing the liquidity premium. Secondly, the spread itself seems less relevant as a measure of banks refinancing conditions given the possibility to obtain funds from the Fed.

In Japan, the interbank money markets were the most destabilized in the period from the fall 1997 to the end of 1998. There was still some turbulence during the ZIRP period but after the introduction of QMEP in March 2001 spreads stabilized. The tensions reappeared to much smaller extent in late 2001 as a consequence of the IT bubble collapse and subsequent bankruptcies of both financial and nonfinancial corporations. Figure 1.16 presents short-term money market spreads: negotiable certificate of deposit (NDC) spread and TIBOR spread, which are indicators of money market tensions. The QMEP period is indeed characterized by relatively stable and small money market spreads which contrasts with the important money markets spreads observed in 2008-2009 in the United States (Figure 1.3a).

The “Japan premium” is another indicator of the health of Japanese banking system. The Figure 1.17 shows the “Japan premium” in euroyen market as a difference between 3-month TIBOR (Japanese banks) and 3-month yen-denominated LIBOR. The positive “Japan premium” from 1997 to 1999 reflected increased credit risk of Japanese banking institutions. The yen-denominated loans to Japanese banks on Tokyo interbank market were more expensive than yen-denominated loans to big international banks on London interbank market.¹⁶ The “Japan premium” was negative in the beginning of the 2008-2009 crisis as the credit risk of banks from Europe and the US was more important than that of Japanese banks. During the ZIRP and QMEP period the Japan premium was quite small and stable.

Both Japanese money market spreads and the “Japanese premium” show that the problems on money markets were much less severe in Japan during the ZIRP and QMEP period than in the U.S. during the 2008-2009 crisis. This could be attributed to the effectiveness of the BOJ ample liquidity provisions and non-payment of interest on excess reserves that had maintained the market stability and encouraged

¹⁶LIBOR contributing banks (Abbey National, Barclays Bank, BNP Paribas, Commerzbank, Credit Suisse, Deutsche Bank, HBOS, HSBC, Lloyds Banking Group, Merrill Lynch (a part of Bank of America), RBS Group, UBS AG).

banks to lend to each other. On the other hand, the money market tensions might have been less severe as the financial institutions finally resolved the NPL problems.

There exist few empirical studies that have measured the impact of unconventional monetary policies on the money market spreads in Japan which seems to confirm that the strains on the interbank market were not the main issue during the QMEP period. Most studies focused on the impact of unconventional measures on Japanese government bonds yield rather than on the credit risk premia paid by financial institutions. This seems to reflect the BOJ focus on providing liquidity to banks via current account balances rather than implementing the liquidity or lending facilities targeting money markets disruption. However, the BOJ easing policies could have reduced money market risk premia indirectly. There might be in particular a spillover effect resulting from arbitrage activities across money markets, which would lower the interest rates paid on the instruments which were not directly used in the BOJ's money market operations. Another possible explanation is that the easy monetary policy environment and low returns induced by QMEP and ZIRP encouraged investors to seek for higher returns and purchase more risky assets.

Baba et al. (2006) measure the impact of unconventional monetary policy in Japan on the funding costs of financial institutions and the risk premia in money market. Specifically they report that the dispersion of issuance rates of negotiable certificate of deposits (NCD) by major banks rose sharply during the banking crisis period in 1997-1998 and fell below the pre-crisis level after the ZIRP was introduced. After the launching of QMEP the dispersion rate declined even further. They provide empirical evidence that this decline in dispersion cannot be attributed solely to creditworthiness of Japanese banks after 1999. Their results show that the ZIRP and QMEP dummies, as well as the BOJ's bill purchasing operations on the money market contributed significantly to reducing the NCD spreads. On the other hand the higher levels of CABs were not significant as explanatory variables. The authors conclude that it was a commitment to maintain the zero policy rate until inflation is steadily above zero that reduced the spreads.

1.4.2 Impact on long-term interest rates

When the official rate is close to zero, the central bank can still stimulate the economy by reducing long-term interest rates. Some of unconventional policies in the United States, in particular the purchases of longer-term Treasury bonds and agency securities, directly aimed at diminishing long-term yields.¹⁷ The impact of the Fed's long-term debt purchases within Quantitative Easing 1 (QE1) on long-term interest rates was analyzed among others by Hamilton and Wu (2012), Gagnon et al. (2011) and (Szczerbowicz, 2011). They found that QE1 indeed lowered nominal long-term interest rates. Gagnon et al. (2010) argue that this reduction was due to portfolio rebalancing effect and decrease in the risk premium. (Szczerbowicz, 2011) finds evidence that unlike QE1, QE2 did not significantly lowered long-term rates.

Interest-rate commitment is another unconventional monetary policy that was intended to lower long-term interest rates. In December 2008, the FOMC's stated that it would maintain the federal funds rate at "exceptionally low levels" for "extended period of time". The expectation theory says that long-term interest rates equal an average of current and expected future short-term interest rates. Therefore, the Fed's commitment to lower the path for future interest rates was supposed to reduce long-term interest rates. However, Gagnon et al. (2011) and (Szczerbowicz, 2011) find that signaling a commitment to keep policy rates low for an "extended period of time" did not contribute to reducing long-term interest rates in the United States during the 2007-2010 crisis.

The empirical evidence concerning Japanese unconventional monetary policy effectiveness (ZIRP and QMEP) shows that they were effective via the commitment channel (expectations management) included in ZIRP and QMEP. Several studies (Oda and Ueda (2007), Okina and Shiratsuka (2004), Baba et al. (2005)) show that the "policy duration effect" of the ZIRP and of the QMEP, i.e. committing to not raising the the policy rate even when the economy and prices enter a recovery rate, had significant impact on the expected short-term rates and therefore lowered long-term yields. On the other hand, the monetary base expansion via current balances account provision was not

¹⁷Chairman Ben Bernanke stated in his speech on December 1, 2008 (Bernanke, 2008) that the Fed's purchases of longer-term Treasury or agency securities on the open market "might influence the yields on these securities, thus helping to spur aggregate demand".

found to be effective in reducing long-term government yields (Oda and Ueda (2007)) even though there is some evidence that these operations might have been effective in some phases via the signaling effect. This effect has an impact on private sector's expectations of the future monetary policy. Important expansion of the central bank's balance sheet often requires purchasing long-term Treasury bonds or other risky assets that the central bank is planning to keep on its balance sheet for an extended period of time. Raising interest rates would expose the central bank to capital losses on the assets it holds. Therefore important increases on monetary base can be associated by financial markets with a signal that the monetary easing will continue longer than previously expected.

Finally, Oda and Ueda (2007) do not find any significant effect of the BOJ purchases of JGB either on risk premia or the expected future short-term rates. These results differ from the U.S. experience where the purchases of long-term government bonds were found to be effective via rebalancing effect and not via the commitment about future short-term rates.

The different impact of the U.S. quantitative easing and the Japanese quantitative easing on long-term interest rates can be attributed to several factors. First of all, the quantities purchased by the BOJ were much smaller than the amounts purchased by the Fed. Second, the Fed clearly insisted on the intended transmission channel of longer-term bond purchases and expected that the private agents portfolio rebalancing would reduce long-term interest rates. The BOJ on the other hand considered bond purchases as a mean to attain the CABs target and avoided relying solely on JBG purchases to achieve the CAB target as they did not want to distort the prices on the JGB market.¹⁸

1.4.3 Impact on inflation expectations

While the impact of alternative monetary policies on money market distress and long-term interest rates was largely discussed in the previous literature, there are not many studies providing empirical evidence on their effect on the long-term inflation expectations. Even though there was a disconnection between narrow and broad money

¹⁸See Maeda et al. (2005).

(Figure 1.7) in the U.S., some of the Fed's unconventional measures were perceived as inflationary by the markets. The liquidity facilities were intended to be short-term but there was still inflationary risk related to them. The markets feared that the huge amounts of liquidity injected could not be easily absorbed once the crisis would be over. The risk linked to longer-term Treasuries purchases was twofold. They were followed by an important expansion of the overall size of the Fed's balance sheet and they changed the maturity structure of the Treasury debt held by the Fed. By preferring the longer-term debt, the Fed took some risk on its balance sheet as the price of long-term bonds fluctuate with time. The outright purchases of agency securities and lending directly to specific financial institutions (Bear Stearns or AIG) was also perceived as risky. These assets were meant to stay on the Fed's balance sheet for long time.¹⁹ Market participants were worried that the Fed would not be able to sell them at the desired price. Subsequent Fed's losses would be covered either with the help of the Treasury via donation of Treasuries for example or by printing money if cooperation of Treasury were not possible. Fed's losses would also have consequences on the Treasury's budget and might incentivize the government and the Congress to put pressures on the Fed, which in turn could compromise the Fed's independence and credibility.

Krishnamurthy and Vissing-Jorgensen (2011) find that QE1 and QE2 increased long-term inflation expectations and therefore reduced real long-term rates. (Szczerbowicz, 2011) results suggest that among all unconventional monetary policies implemented QE2 and rescue operations of individual financial institutions increased far-ahead forward inflation expectations. This increase in long-term inflation expectations seems to be a desirable effect that counters deflationary tendency and brings inflation expectations to their historical levels (Figure 1.18).

Unlike in the United States, the unconventional monetary policies implemented by the BOJ were clearly intended to have inflationary impact as the deflation became a major problem in Japan. The large increase in CABs were designed to encourage Japanese banks to extend lending to economy. However, the worsening of firms' and banks' balance sheet problems impaired this transmission mechanism. Indeed,

¹⁹Bernanke (2010b).

according to the survey of empirical analysis on the effectiveness of QMEP conducted by Ugai (2007), the impact of an increase in the monetary base on the inflation rate and price level are small or not identified at all.

Based on this evidence, it seems that the Fed's unconventional measures had bigger impact on inflation expectations. This might be due to the timing of the Fed's intervention. It is very difficult to go out from the liquidity trap once the deflation is present and the Fed reacted to banks' difficulties before inflation had become negative. Moreover, the quantity and diversity of assets purchased by the Fed was much bigger which made the Fed's deflation-fighting more credible. It is also possible, as mentioned before, that the agents saw in these unconventional purchases some potential risk to the Fed's independence.²⁰

1.5 Risks of unconventional monetary policies

The central banks in the United States and in Japan employed unconventional monetary policies to diminish the amount of risk held by private agents in several ways. They provided ample amounts of liquidity in form of excess reserves (BOJ and Fed) or government bonds (Fed, as a part of Term Securities Lending Facility) in exchange for less liquid assets, taking over banks' liquidity risk.

Furthermore, they enlarged the eligible collateral for their credit operations and directly purchased unconventional risky assets. The Fed exposed its balance sheet to credit risk to greater extent than the BOJ did. First of all the BOJ increased less its balance sheet. Second, the expansion was principally done with the long-term JGBs whereas the Fed took on its balance sheet important amounts of MBS, ASB and the assets of AIG and Bear Sterns. The central bank purchases of risky assets and accepting them as a collateral reduced the private cost of credit risk. In other words, the Fed, and to much smaller extent the BOJ, took on their balance sheet the credit risk that the private agents did not want to hold.

Furthermore, the purchases of longer-term government debt that con-

²⁰The BOJ became independent in 1997 (the Bank of Japan Act was revised in June 1997) and put great effort in communicating that the Japanese government cannot influence its monetary decisions. Mishkin (2006) even says that "the governor and fellow board members took independence literally and refused to cooperate with the government when the economic conditions called for such cooperation".

tributed significantly to the central bank balance sheet expansion in Japan and in the US diminished the sovereign risk held by private agents. Both the Fed and the BOJ purchased directly longer-term government bonds which in fact allowed the government to increase the borrowing without having to face the higher interest rates. In fact, all along the QE period the long-term interest rates in Japan and in the U.S. remained at a very low level even though the government increased substantially its debt.

Finally, both central banks made a commitment concerning keeping the interest rates at exceptionally low levels for an extended period of time (Fed) or maintaining the conditions for the interest rates to stay zero until inflationary concerns are dispelled (BOJ) which diminished the interest risk borne by market participants.

Unconventional balance sheet management came with some possible cost and risks. By providing almost unlimited amount of funds to banks, the Fed practically replaced interbank market. The interbank loans in the U.S diminished substantially and the money market spreads stay at much higher levels then in the period preceding the subprime crisis. The malfunctioning of the interbank market seems permanent now which raises an important questions concerning the future of that market and the impact on the overall heath of the banking system. Indeed, an easy access to funding and little collateral requirements can make dependent the weak banks with insufficient capital on the central bank's liquidity. The funding provided to such insolvent banks is likely not to be transformed into lending to companies and households. This argument was often made with respect to BOJ accused to artificially maintain "zombie" banks and in this way postponing the recovery. During the Japanese crisis the important provision of liquidity had indeed no impact on aggregate lending. Only once the disposal of bad loans and recapitalization of the banks took place the banks started lending again. Therefore, the central bank liquidity relieve banks with funding difficulties but also lessen the pressure on banks to reform.

Another important issue is linked to the credit risk that the Fed accepted on its balance sheet. As the Fed's profits are transferred *in fine* to the Treasury, the taxpayers are directly impacted by the central bank decision. The Fed protected itself by imposing important

haircuts on the accepted collateral and the purchased assets. However, the Fed intends to keep important part of its assets for a long time. As long as the economy recovers as planned, the Fed will make a profit on these assets. If however another shock hits the economy the Fed could bear losses and face the dilemma whether to ask the Treasury for rescue (recapitalization, lending of Treasuries) or just monetizing the loss. Both of these outcomes seem undesirable. Monetizing of losses threatens credibility of the Fed. On the other hand, covering the losses by the Treasury bring up the risk of overstepping into fiscal and distribution policies. Traditionally, the central bank would buy securities at the same prices as other financial market participant would buy them. Since the recent crisis however, the Fed purchased the assets that were unattractive to private agents and arbitrarily decided which market participants would benefit from its lending operation. For instance, in September 2008 the Fed agreed to transform Morgan Stanley and Goldman Sachs into bank holding companies which allowed them to have access to cheap Fed's liquidity. Also, the Fed participated in the Bear Stearns and AIG rescue operations but refused to do so in Lehman Brothers case. It seems preferable that such decisions are taken directly by the Treasury.

The main risks of the Fed are therefore linked to the credit risk that it bears on its balance sheet. The BOJ was much more cautious about buying risky assets. However, the unconventional strategy chosen by the BOJ proved insufficient to stimulate lending or increase inflation.

1.6 Conclusion

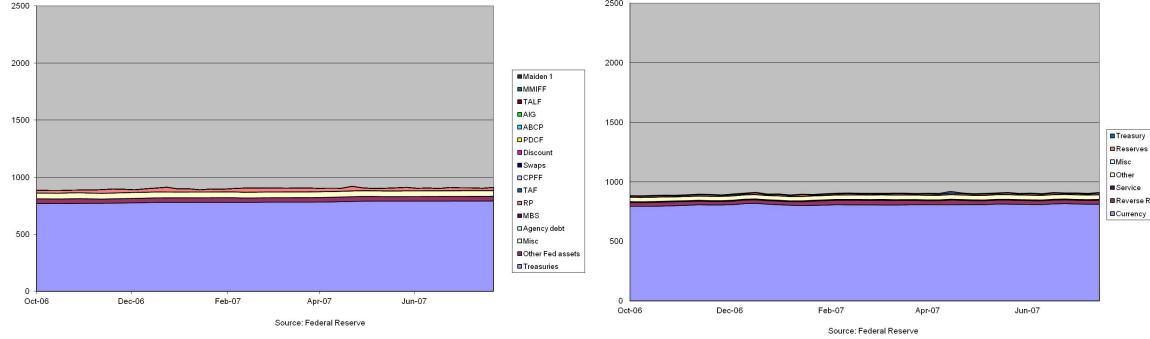
This chapter emphasized the diversity of unconventional monetary policies. Even though both Bank of Japan and Federal Reserve implemented three types of unconventional monetary policies, namely expectation management, monetary base increase and purchases of risky assets, the objectives and results of these policies were not the same. The country-specific problems and financial environment played important role in the unconventional monetary policy design. Furthermore, the results of the non-standard measures depended on their intensity and scale. We showed that the Fed increased its balance sheet

as a result of large-scale interventions in specific financial markets segments (“asset-driven balance sheet management”) while the BOJ changed the composition of its balance sheet as a result of its raising excess-reserves target. The comparison of the commercial banks’ balance sheets in the United States and in Japan underlines at the same time country-specific characteristics of the U.S. and Japanese banking sector and the possible impact of unconventional monetary policies in each country. In Japan the aggregate lending diminished more than in the U.S. which at the same time illustrates deeper problems of Japanese companies and gives credit to aggressive U.S. credit easing monetary policy. On the other hand, the disruption of interbank market in the U.S. has been much more pronounced than in Japan and the Fed’s almost unlimited liquidity and interest-bearing excessive reserves might have contributed to this phenomenon. Finally, the Fed’s important interventions in chosen markets (credit easing) contributed to lower interest rates of corresponding assets while in Japan the smaller-scale JGBs purchases did not diminish their interest rates. These interventions increased significantly the credit risk that the Fed bears on its balance sheet and makes its exit strategy more challenging. The BOJ was much more cautious about buying risky assets but this unconventional strategy proved insufficient to stimulate lending or increase inflation.

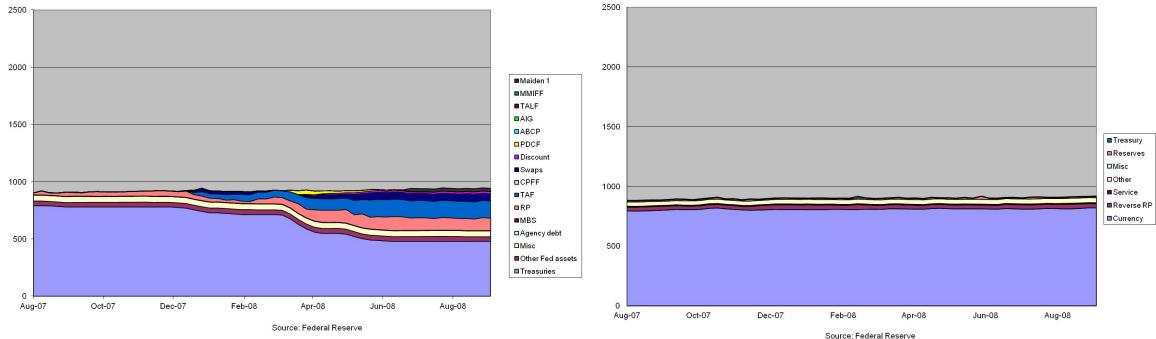
1.7 Annexes

A1. Figures

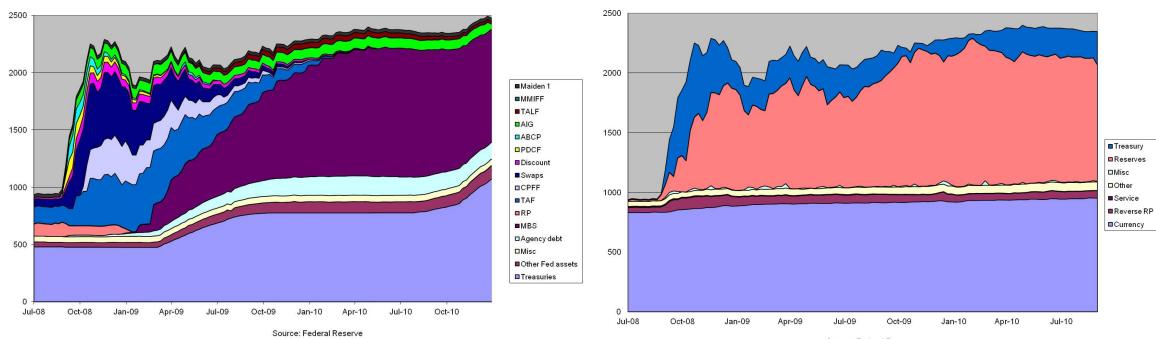
Figure 1.1: Quantitative Easing and Credit Easing in practice: the case of the Fed



(a) Before crisis: “Normal times”. Fed’s Assets (left) and Liabilities (right), October 2006-July 2007

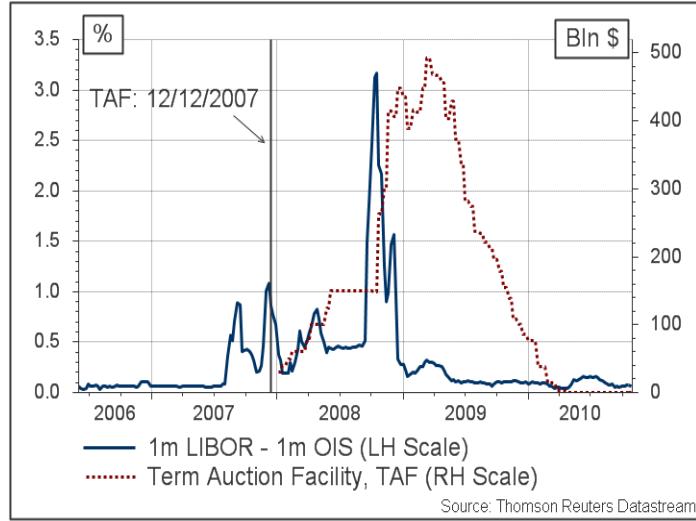


(b) First stage of the crisis: Pure Credit Easing. Fed’s Assets (left) and Liabilities (right), August 2007-September 2008

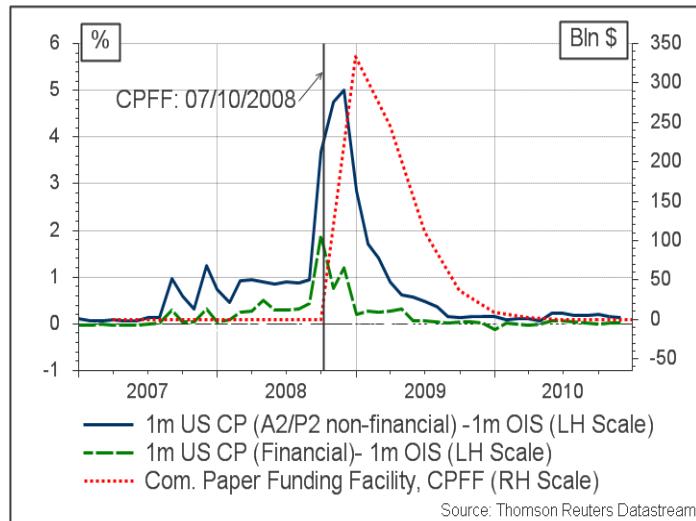


(c) Second stage of the crisis: Mix of Credit and Quantitative Easing. Fed’s Assets (left) and Liabilities (right), September 2008-November 2010

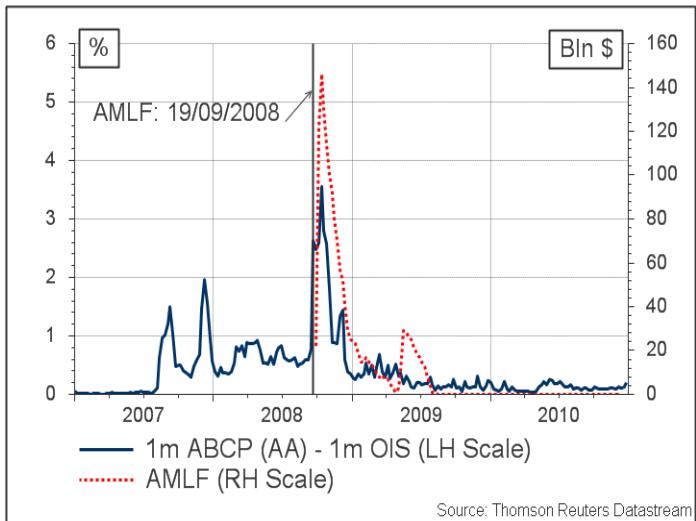
Figure 1.2: Spreads on financial markets and Fed's liquidity facilities



(a) LIBOR-OIS Spread and Term Auction Facility (TAF)

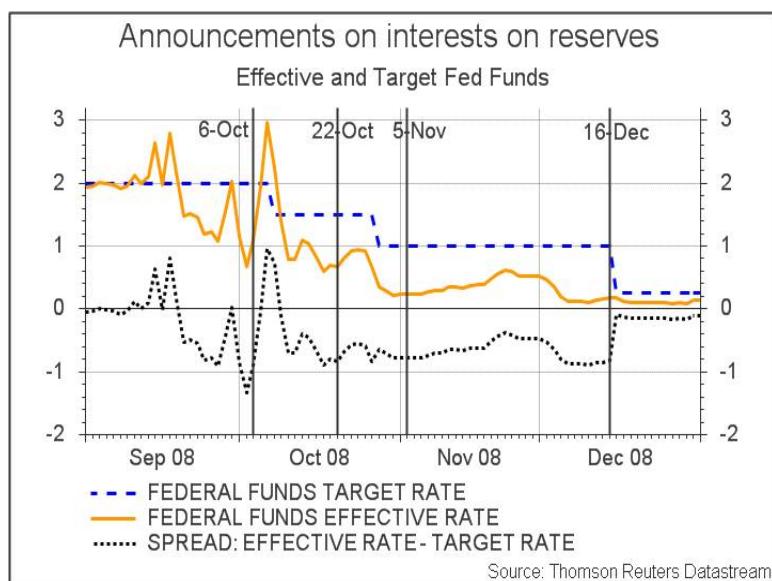


(b) Commercial Paper (CP) Spreads and Commercial Paper Funding Facility (CPFF)



(c) Asset-backed commercial paper (ABCP) - OIS spread and ABCP Money Market Mutual Fund Liquidity Facility (AMLF)

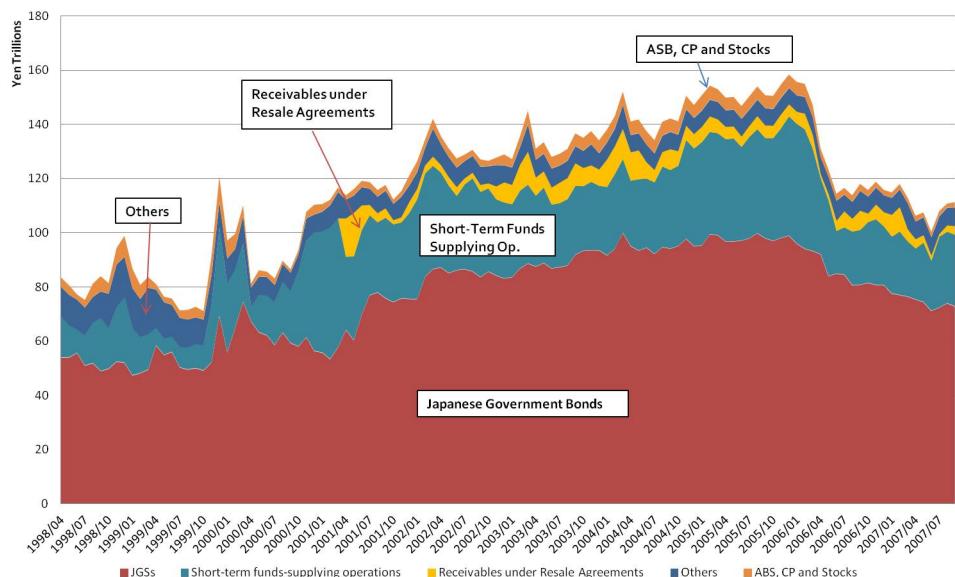
Figure 1.3: Interest rates on excess reserves at the Fed and the Fed Funds spread



Fed announcements: 06/10/2008 Fed begins to pay interest on depository institutions' required and excess reserve balances; 22/10/2008 and 05/11/2008 Fed increases the interest rate paid to depository institutions on excess balances; 16/12/2008 Fed establishes interest rates on required and excess reserve balances of 0.25%.

Figure 1.4: BOJ balance sheet

Assets of the Bank of Japan



Liabilities of the Bank of Japan

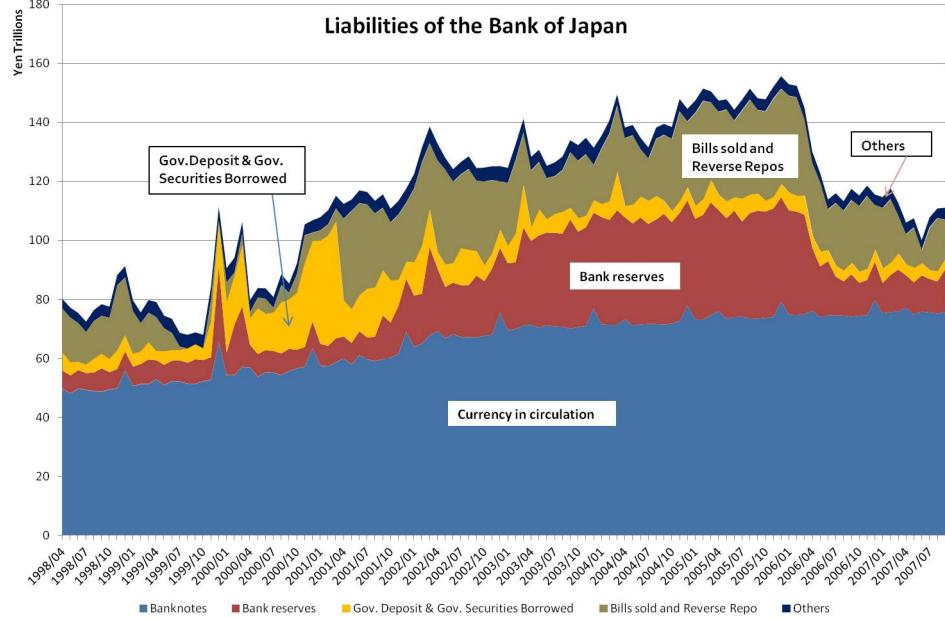
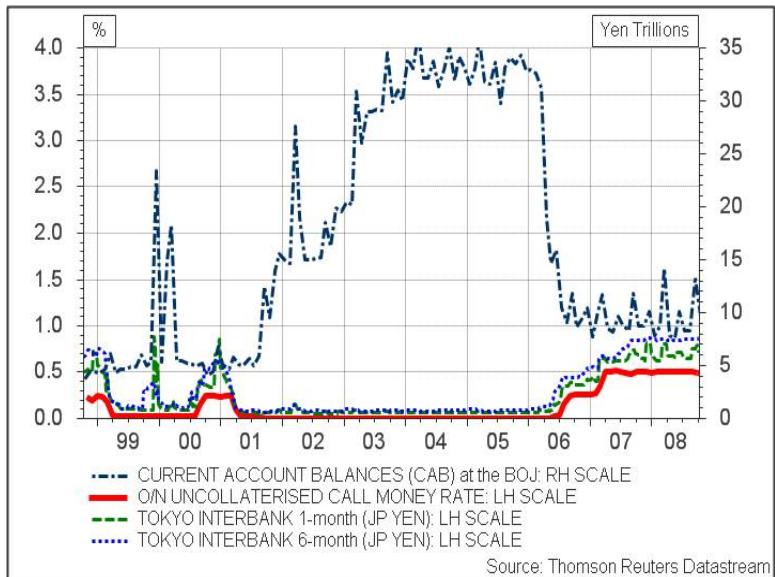
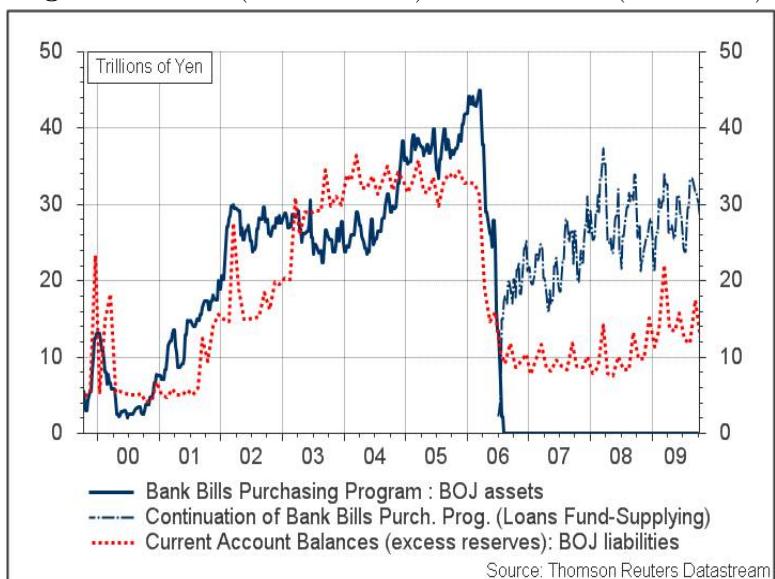


Figure 1.5: Current Account Balances and the Money Market Rates



Source: Thomson Reuters Datastream

Figure 1.6: CAB (BOJ liabilities) and Bank Bills (BOJ assets)



Source: Thomson Reuters Datastream

Figure 1.7: Monetary Aggregates in the United States and Japan

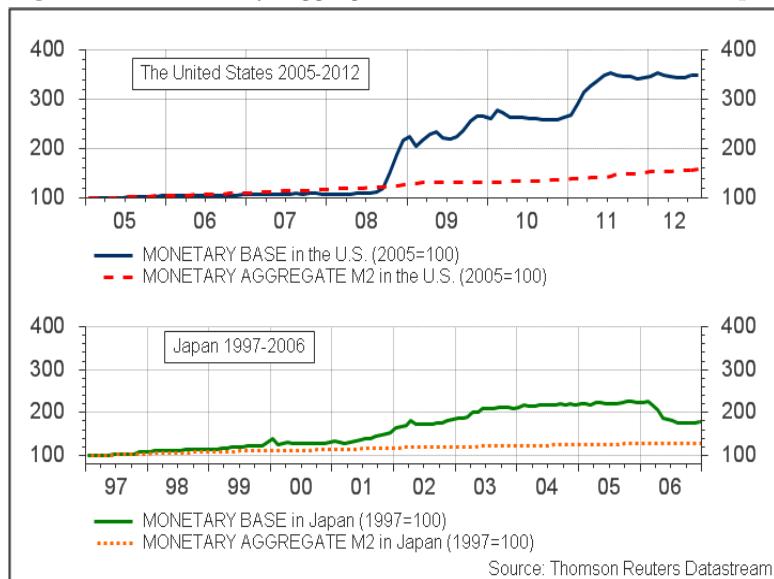


Figure 1.8: Aggregate U.S. commercial bank lending

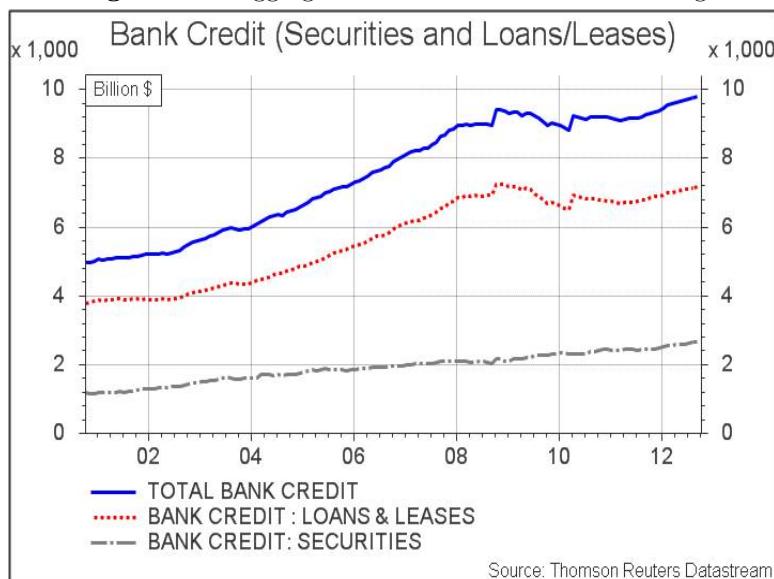


Figure 1.9: Securities holdings (U.S. commercial bank)

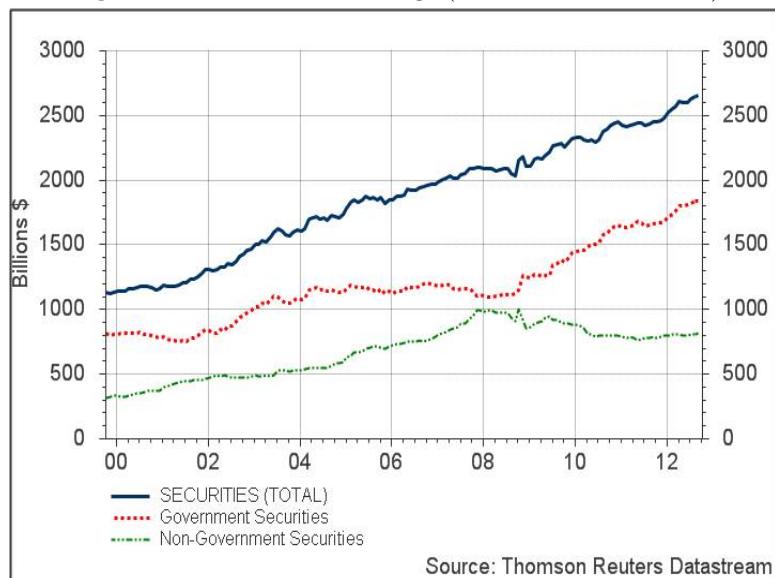
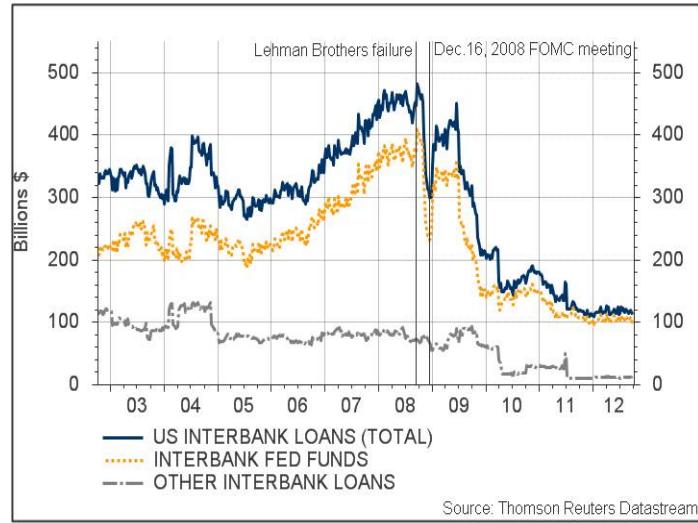
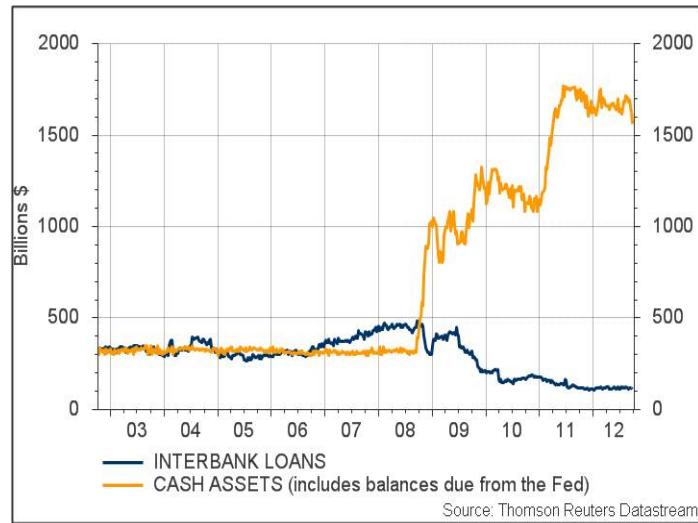


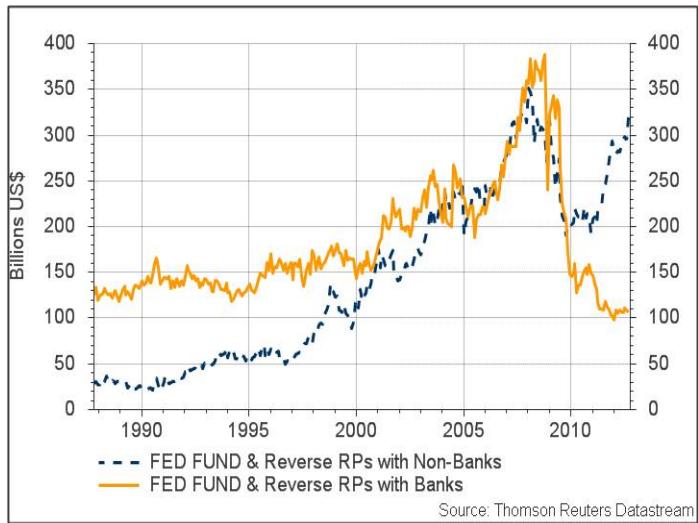
Figure 1.10: Interbank Lending (U.S. Commercial Banks)



(a) Interbank Loans



(b) Interbank Loans and Cash Assets



(c) Fed Funds and Reverse Repos: Banks and non-banks

Figure 1.11: Aggregate bank lending in Japan (Domestically Licensed Banks)

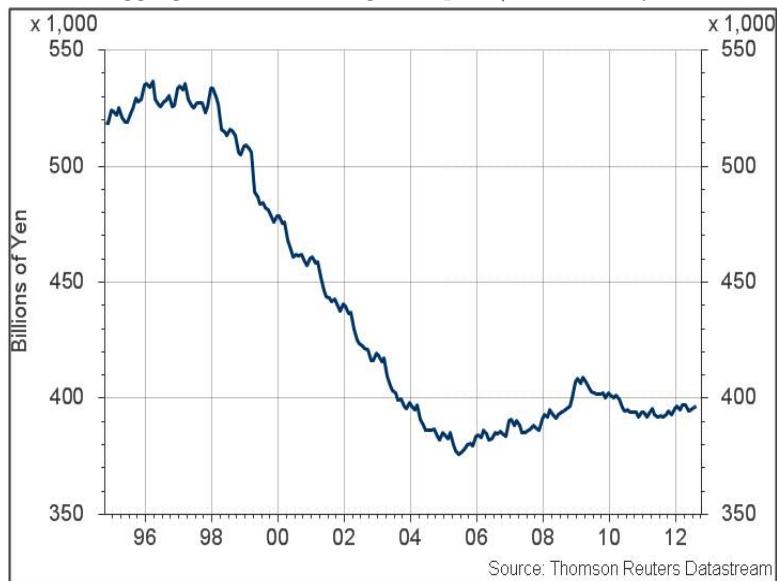


Figure 1.12: Investment Securities (Domestically Licensed Banks in Japan)

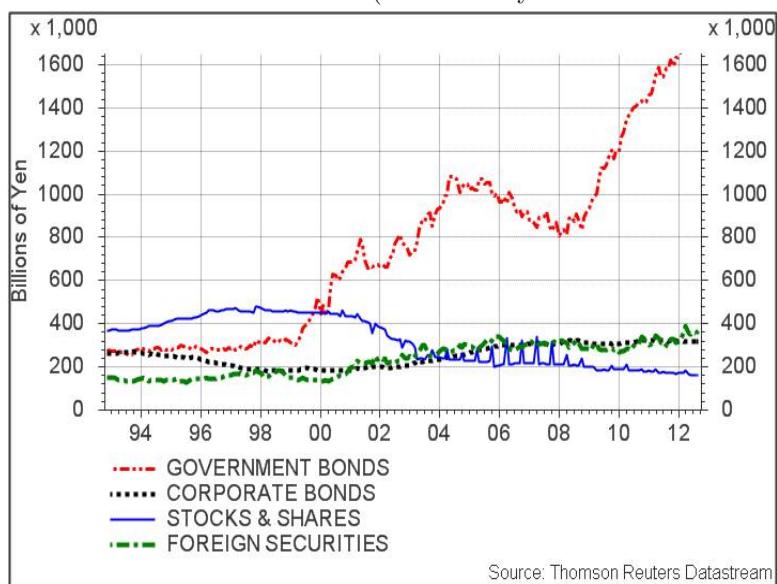


Figure 1.13: Deposits in Banks and at the BOJ (Domestically Licensed Banks in Japan: Assets)

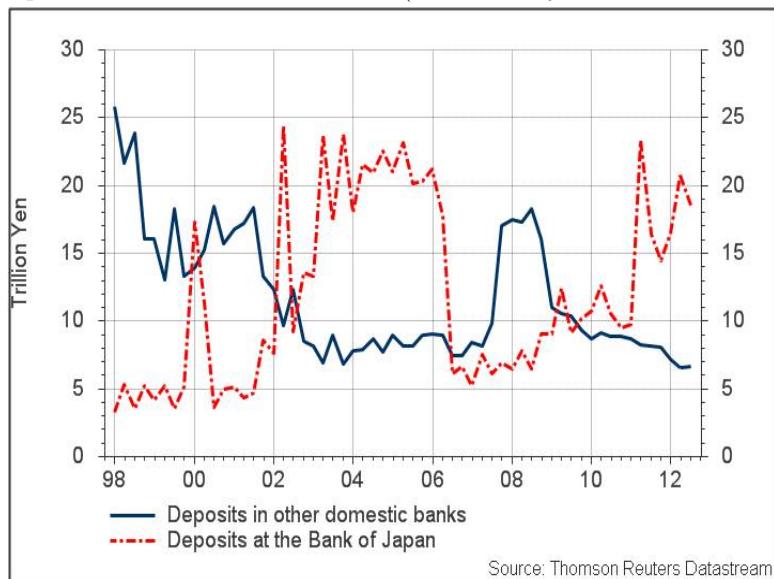


Figure 1.14: Outstanding amounts in Call money market

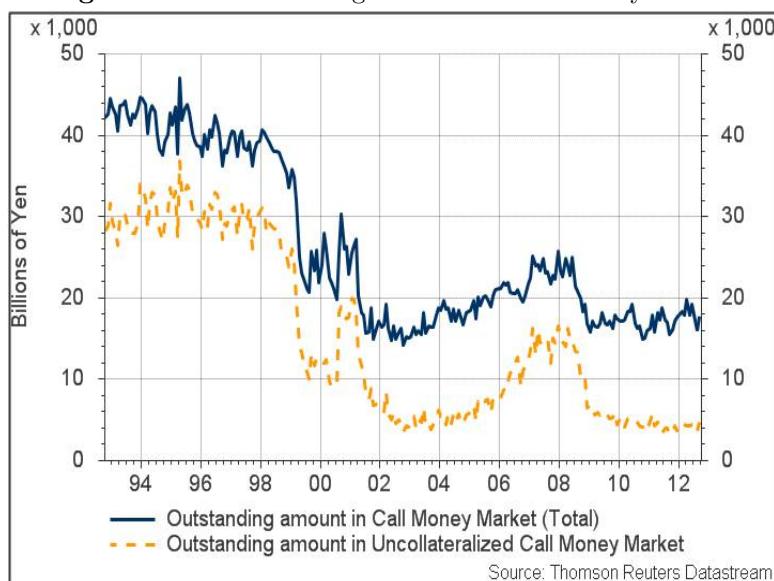


Figure 1.15: Japan: Non Performing Loans and Aggragate Bank Lending

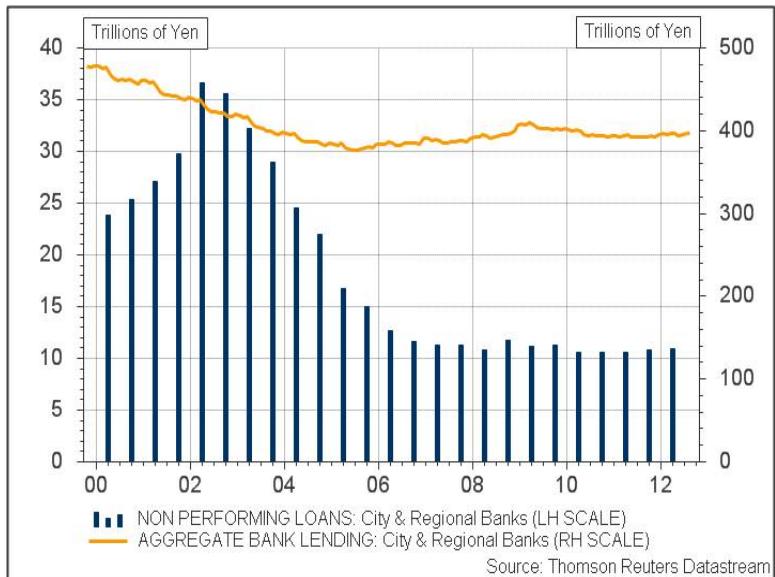


Figure 1.16: Negotiable Certificate of Deposit (NDC) and TIBOR spreads

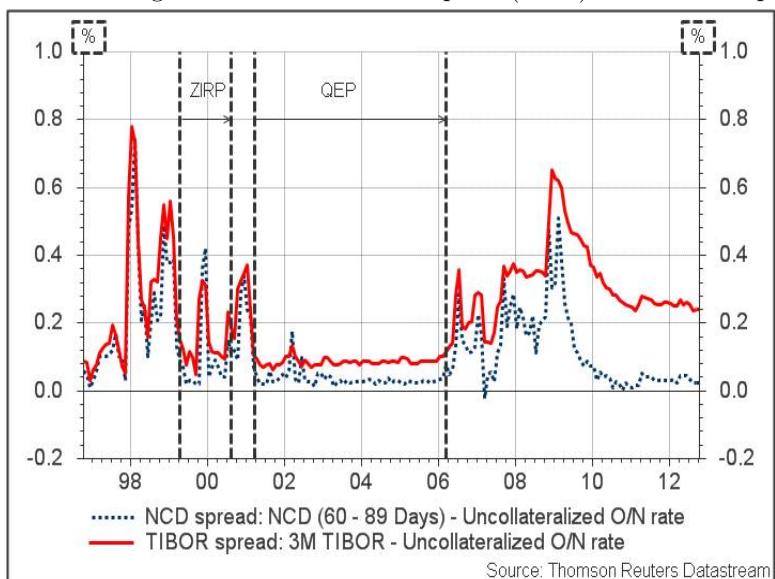
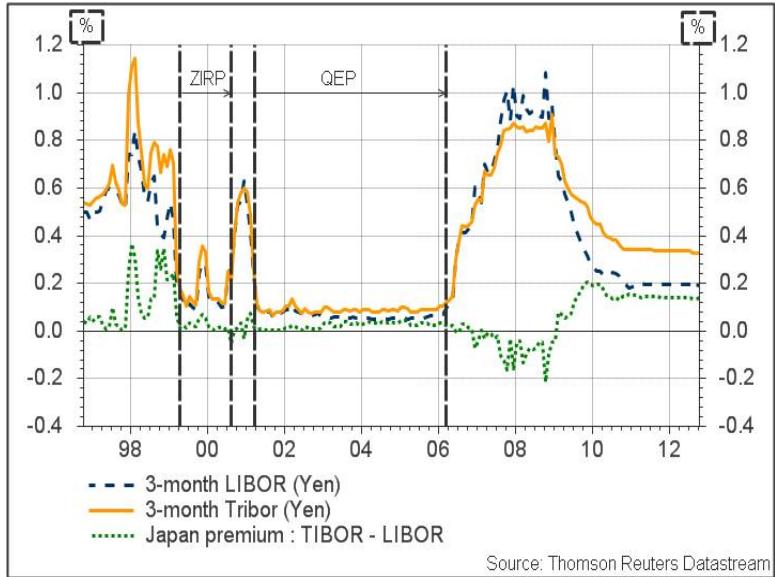
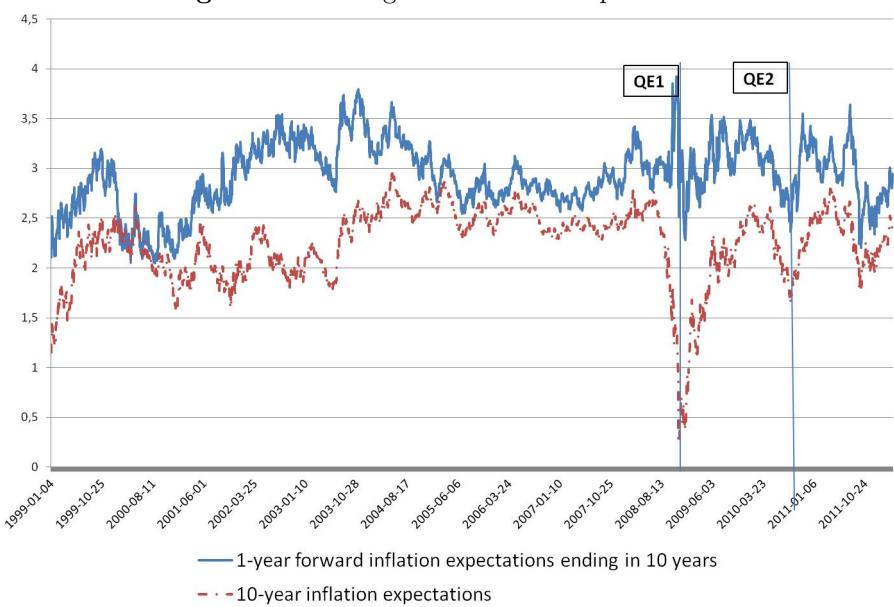


Figure 1.17: “Japan premium” in the Euroyen market



Source: Thomson Reuters Datastream

Figure 1.18: Long-term inflation expectations in the United States



A1. Tables

Table 1.1: Unconventional monetary policies : BOJ and Fed

	Bank of Japan (1999-2006)	Federal Reserve (2007-2010)
Expectations management	a) ZIRP until deflationary concerns are dispelled (04/1999) b) QMEP until the CPI inflation becomes stably at or above 0% (03/2001)	Exceptionally low Fed Funds levels for: a) some period of time (12/2008) b) extended period of time (03/2009) c) at least through mid-2013 (08/2011) d) at least through late 2014 (01/2012) d) at least through mid-2015 (09/2012)
Credit easing	Purchases of ABCP, ABS, equities from banks, long-term Japanese government bonds; CP repos	Purchases of CP, ABS, MBS, longer-term Agency and Treasury bonds
Quantitative easing	Targeting the current account balances; increase in monetary base of 50% via long-term JGB and short-term lending to banks	Increase in monetary base of 250% via longer-term Treasury bonds and Agency bonds and MBS

Table 1.2: Central bank balance sheet management

(a) Simplified balance sheet of the central bank in normal times

<i>Assets</i>	<i>Liabilities</i>
Conventional assets	Excess reserves
	Money in circulation

(b) Credit easing

<i>Assets</i>	<i>Liabilities</i>
Conventional assets ↓	Excess reserves
Unconventional assets ↑	Money in circulation

(c) Quantitative easing

<i>Assets</i>	<i>Liabilities</i>
Conventional assets ↑	Excess reserves ↑
	Money in circulation

(d) Mix of Quantitative and Credit easing

<i>Assets</i>	<i>Liabilities</i>
Conventional assets	Excess reserves ↑
Unconventional assets ↑	Money in circulation

Table 1.3: Fed's liquidity facilities

- **TAF:** discount window loans to depository institutions
- **TSLF:** term loans of Treasury securities to primary dealers
- **PDCF:** discount window loans to primary dealers
- **ALMF:** loans to depository institutions to purchase ABCP from money market mutual funds
- **CPFF:** liquidity backstop to U.S. issuers of commercial paper
- **MMIFF:** supports a private-sector initiative to provide liquidity to U.S. money market investors
- **TALF:** supports the issuance of ABS collateralized by student loans, auto loans, credit card loans, and loans guaranteed by the Small Business Administration

2 Were the Fed's unconventional monetary policies effective during the 2007-2010 crisis?¹

2.1 Introduction

The recent financial crisis has made clear that the conventional monetary policy through interest rates steering, was no longer sufficient to bring back the financial stability and economic recovery. Faced with severe tensions on financial and monetary markets the Federal Reserve developed several unconventional monetary measures. First of all, they introduced new liquidity facilities which were gradually expanded to include wider range of collateral and bigger number of counter-parties. After the collapse of Lehman Brothers, the Fed lowered the federal funds target rate nearly to zero and implemented unconventional monetary policies even more intensively. In particular, they started interventions in specific market segments and initiated the asset purchase programs including commercial papers, longer-term Treasury bonds and agency debt and MBS. Figure 2.1 illustrates the way the unconventional policies affected the Fed's balance sheet: since the beginning of the crisis the composition of the Fed's assets was significantly altered and the size of the balance sheet more then doubled. In this chapter we bring empirical evidence on the effectiveness of these new policies: in particular, on the effectiveness in lowering long-term interest rates and reducing the Libor-OIS spread. When short-term interest rates are close to zero, the Fed can still stimulate aggregate demand by reducing long-term rates. Furthermore, by reducing tension on interbank market the Fed can improve transmission mechanism

¹I would like to thank my supervisors Pierpaolo Benigno and Henri Sterdyniak for their guidance and valuable advice. I am also grateful to Etsuro Shioji for helpful comments during my research stay in Hitotsubashi University in spring 2010. This paper has also benefited from helpful discussions and suggestions from Nicola Borri, Refet Gürkaynak, Yukinobu Kitamura, Philippe Martin, Giuseppe Ragusa and seminar participants at Sciences-Po Economics Department, OFCE and LUISS Guido Carli. Any errors are mine. Financial support from LUISS Guido Carli, Collège doctoral franco-japonais and Università Italo Francese is gratefully acknowledged. An earlier version of this paper was circulated under the title: "Are unconventional monetary policies effective?"

through credit markets.

Beyond efficacy, the unconventional monetary measures raised the question of the anchorage of long-term inflation expectations. Raising inflation expectations was not an explicit objective of the Fed throughout the crisis and indeed in several occasions they reiterated the importance of maintaining price stability. Moreover, as shown in Figure 2.2, the monetary base expansion did not affect much the broader money aggregates. Nevertheless, managing inflation expectations along with implementing unconventional monetary policies is a controversial issue. There are several reasons to think that non-standard policies might affect the anchorage of long-run inflation expectations and threaten the Fed's credibility and independence. First, expansion of monetary base can encourage the doubts about the Fed's ability to absorb the excessive liquidity once the crisis is overcome. Second, without explicit announcement of future taxes increase or expenditure reduction, agents might expect the growing public debt to be monetized. Finally, the Fed's purchases of risky assets could potentially lead to credit losses and smaller transfers to the Treasury which in turn might trigger some political pressure on the conduct of monetary policy. On the other hand, potential inflationary effect of unconventional monetary policies seems desirable in the context of prolonged recession. Increasing inflation expectations allows to counter the deflationary spiral and reduce real interest rates. In that sense, unconventional monetary policies might spur aggregate demand even when the policy rates approached zero and the conventional monetary policy lost its effectiveness.

To assess the impact of unconventional monetary policies on the Libor-OIS spread, long-term interest rates and long-term inflation expectations we employ regression-based event study. First, we identify and classify unconventional monetary announcements. We also list conventional monetary policy surprises and fiscal policy news. Then, we investigate the behavior of selected asset yields over short periods surrounding the policy statements. Under efficient markets, the effect of the policy announcements should be immediately reflected in asset prices. First, we measure the impact of all announcements on the three-month Libor-OIS spread and ten-year nominal interest rates so as to evaluate the effectiveness of the non-standard monetary

measures. Second, we evaluate their impact on long-term inflation expectations. We rely on dummy variables to discriminate between days with or without announcement. In line with the previous literature Kuttner (2001) we assume that financial markets react only to the announcements that were not fully anticipated. We define the surprise component of dummy variables based on information included in specialized articles in Wall Street Journal and Reuters before and after the event.

Our contribution to the empirical literature on the effects of unconventional monetary policies is three-fold. First, we create the database of monetary and fiscal announcements, and their surprise components, for the United States during 2007-2010. Second, we provide the first empirical evidence on the impact of all unconventional monetary policies on long-term inflation expectations. Third, we bring new evidence on their effectiveness using the regression-based event study. This approach allows us to estimate the effect of all policies simultaneously which seems particularly important during the crisis as several types of announcement arrived on the same day. We compare the monetary policy responses to fiscal policy responses and take into consideration the bad news about the health of important financial institutions.

We find that the liquidity facilities other than TAF and government bailouts reduced the Libor-OIS spread. The outright purchases of longer-term Treasury securities and agency debt and MBS within QE1 lowered long-term interest rates. Finally, we find evidence that the Fed's rescue operations, QE2 and fiscal stimulus announcements raised long-term inflation expectations.

The chapter is organized as follows. The literature is reviewed in the following section. The data and methodology are presented in section 2.3. In section 2.4 we estimate the impact of the announcements on long-term interest rates, the Libor-OIS spread and long-term inflation expectations and we present the main results. Section 2.5 concludes.

2.2 Literature review

There exists an extensive literature which evaluates the effects of unconventional monetary policies but the empirical evidence on this subject is yet not conclusive. Bernanke et al. (2004) analyze the effective-

ness of different unconventional monetary tools in lowering the long-term interest rates in the United States and in Japan based on policy examples before the 2007-2010 crisis. They group the non-standard policies into three categories: (1) Expectation management strategy (commitment about the future path of interest rates); (2) Expansion of monetary base (quantitative easing); (3) Changes in the composition of the central bank balance (credit easing). Their empirical evidence confirms to the large extent the effectiveness of shaping public expectations and changing the relative supplies of securities in the United States. However, the impact of unconventional policies implemented by the Bank of Japan during the deflation period is more ambiguous. According to the empirical studies surveyed by Ugai (2007), the commitment effect lowers considerably long-term interest rates but the expansion in monetary base and the change in the composition of the central bank balance sheet were found to have little impact or none at all.

During the recent economic crisis the unconventional monetary policies were extensively implemented by many central banks. Since then, several descriptive (Borio and Disyatat (2010), Meier (2009)) and theoretical (Adrian and Song Shin (2010), Càrdia and Woodford (2011), Gertler and Karadi (2011)) studies contributed to the better comprehension of the non-standard monetary policies.

The empirical research focused on the impact of unconventional monetary policies on the reduction of interbank risk premia. There is a debate in the recent literature concerning the effects of new liquidity facilities on the Libor-OIS spread. Several papers (Taylor and Williams (2009a); Wu (2011); McAndrews et al. (2008)) evaluate the effectiveness of the Term Auction Facility (TAF) and report conflicting results. Taylor and Williams (2009a) claim that TAF cannot have an impact on the Libor-OIS spread because it is mostly due to credit risk and not the liquidity risk. On the other hand, Wu (2011) maintains that the spread was caused by the misallocation of liquidity and that the financial strains in the interbank money market were alleviated after TAF was implemented. McAndrews et al. (2008) evaluate the impact of not only the TAF operations but also of the TAF announcements and conclude that they diminished the spread. However, their sample includes only the announcements made until April 24, 2008.

We bring additional empirical evidence on the impact of new liquidity facilities on money market distress. First, we take into consideration all liquidity facilities implemented by the Fed during the 2007-2010 crisis. Second, we use the announcements during the whole period of the crisis. Third, we compare the effectiveness of liquidity facilities in reducing money market tensions to other monetary and fiscal policy responses.

Aït-Sahalia et al. (2010) consider all macroeconomic and financial sector policy announcements in the United States, the United Kingdom, the euro area and Japan and find that both macroeconomic and financial sector policy announcements were associated with reductions in the Libor-OIS spreads.

In this chapter we also consider all policy announcements but we take different approach: regression-based event study. This approach allows us to estimate the effect of all types of policy announcements simultaneously. This is important during the crisis given that several announcements arrived on the same day. In particular, it allows us to take into consideration the bad news about the health of important financial institutions which very often were driving the policy responses on the same day and had opposite impact on the spread.

The impact of the Fed's long-term debt purchases on long-term interest rates is analyzed by Hamilton and Wu (2012) and Gagnon et al. (2011). They find that QE1 lowered nominal long-term interest rates. We contribute to the discussion on the effectiveness of long-term Treasury and agency debt purchases through the regression-based event study methodology. Moreover, we measure the impact of QE2 and other unconventional monetary policies. As Hamilton and Wu (2012) and Gagnon et al. (2011) we find that QE1 reduced long-term interest rates. However, we show that QE2 did not have significant impact on these rates. Krishnamurthy and Vissing-Jorgensen (2011) analyze via event study the impact of QE1 and QE2 on long-term interest rates. They find that both operations had reducing impact on long-term nominal rates. Our results for QE2 are different as we consider in our event study more announcements than Krishnamurthy and Vissing-Jorgensen (2011), and in particular the speech of Ben Bernanke on August 27, 2010 in Jackson Hole (Bernanke, 2010a) that was understood as a first indication of QE2 (see subsection 2.3.4 B for details).

While the impact of alternative monetary policies on interest rates and money market distress was largely discussed in the previous literature, their effect on long-run inflation expectations is still poorly known. Recently, Krishnamurthy and Vissing-Jorgensen (2011) studied the impact of QE1 and QE2 on inflation expectations measured as a difference between CDS-adjusted Abb rates and TIPS. In this chapter we investigate the consequences of all unconventional monetary policies on the anchoring of long-term inflation expectations. To this purpose we focus exclusively on long-term inflation expectations that we measure using far-ahead forward inflation compensation as in Gürkaynak, Levin and Swanson (2010).

2.3 Methodology

2.3.1 Regression-based event study

We apply the regression-based event study methodology in order to evaluate the impact of monetary and fiscal policy announcements on the Libor-OIS spread, long-term interest rates and long-term inflation expectations in the United States during the 2007-2010 financial crisis. This approach is employed by Cook and Hahn (1989) and Kuttner (2001) among others to measure the response of nominal interest rates to the central banks' official rates changes. Event study methodology allows testing the impact of an economic event on financial market data.² In modern financial markets, an event that affect these future payoffs should be reflected in asset prices over a short period of time. Therefore, the impact of this event can be measured by examining security prices surrounding the event.

In this chapter we examine one or two-day response of ten-year interest rates, three-month OIS-Libor spread and far-ahead forward inflation compensation to different policy announcements. In particular, we take into account the FOMC interest rates decisions, unconventional monetary policy announcements, fiscal policy announcements and failures of big financial institutions. We rely on dummy variables to discriminate between days when announcements were made or not. In line with the previous literature (see for example Kuttner (2001)) we assume that financial markets react only to the announcements

²See MacKinlay (1997).

that were not fully anticipated. Some previous studies use “surprise dummy” variables to take into account unanticipated component of announcements. Bernanke et al. (2004) construct surprise dummy based on the set of commentaries written before and after each statement. We define our surprise dummy variables based on specialized articles in Wall Street Journal and Reuters before and after the event.

2.3.2 Data

In this study we use daily data sets from January 4, 1999 to December 31, 2010 with the exception of the OIS rates which were available only from November 26, 2003 and CDS rates, available from January 1, 2001. We omit the observation for the 17/09/2001 FOMC inter-meeting from our sample, as in Bernanke and Kuttner (2005) and others, since this is the first day of trading following the September 11th attacks. The data on the one-year far ahead forward inflation were taken from

<http://www.federalreserve.gov/econresdata/researchdata.htm>.³ The data on other interest rates were obtained from Datastream, Bloomberg and Reuters.

2.3.3 Date and time of announcements

We put together a complete list of dates of monetary policy announcements from January 4, 1999 until December 31, 2010. Until August 2007 the news concerning the monetary policy were released at 14:15 Eastern Time after regularly scheduled FOMC meetings. Since the beginning of the subprime crisis, the Federal Reserve introduced several new measures and intensified their communication. For instance, 12 monetary policy announcements were made in 2006 vs. 80 announcements in 2008. We also report fiscal announcements and failures of important financial institutions during the crisis. Table 2.1 and Table 2.2 contain the list of all announcements as well as the dates of release.

³Dataset from Gürkaynak, Sack and Wright (2010).

2.3.4 Types of announcements

We classify unconventional monetary policy announcements into five categories: interest rates commitment, long-term Treasury bonds purchases, agency debt and MBS purchases, liquidity facilities and the Federal Reserve's rescue operations. We also include conventional monetary policy and fiscal policy announcements into our analysis in order to compare the effectiveness of unconventional monetary policies to other types of policy responses.

In developed financial markets, asset prices should react only to the unexpected component of the announcements. Therefore, for each kind of policy, we define a measure of deviation of the actual statements from what was expected by financial markets participants.

- Conventional monetary policy

FOMC interest rates decisions

The surprise component of the FOMC interest rates decisions is evaluated using federal funds futures (Kuttner (2001)). These contracts are settled based on the average effective federal funds rate that is realized for the calendar month specified in the contract. It is therefore possible to infer from these instruments the market expectations of the FOMC decisions at future meetings. The daily changes in the current-month futures contract rate reflect the changes in market's expectations of the fed funds rate during the remainder of the month. The surprise component of the FOMC interest rates decision on day t of month s is given by:

$$\Delta x_{s,t} = \frac{m_s}{m_s - t} (fff_{s,t}^0 - fff_{s,t-1}^0)$$

where:

$fff_{s,t}^0$ is the current month fed funds futures rate on day t of month s
 m_s denotes the number of days in month s with $t = 1, \dots, m_s$ and $s = 1, \dots, 12$. Since the contract settlement price is based on the average of the effective fed funds rates, the scaling factor $\frac{m_s}{m_s - t}$ adjusts the unexpected component proportionally to the number of days in the month affected by the change.⁴

⁴For the interest rates decisions that occur in the last 7 days of the month, we use the next-month unscaled contracts to avoid the effect of month-end noise and multiplying by a very large scale factor (30 or 31 on the

In our regression we include the FOMC decisions about reducing, raising and maintaining the federal funds rate. The decisions to maintain the target rate may also be surprising for financial markets.

- **Unconventional monetary policies**

A. Interest rates commitment

Under this class we consider statements through which the Federal Reserve impact the expectation of the future federal funds rates. On December 16, 2008 the FOMC cut the fed funds rate to a range of zero to 0.25% and additionally stated that “the Committee anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time”. On March 18, 2009 they made a stronger pledge announcing that the exceptionally low levels of fed funds rate would be maintained “for an extended period” rather than “for some time”. In this way, the Fed communicated to markets its commitment to lower the path for future interest rates. Expectations management has been proven effective in lowering long-term interest rates during the deflation period in Japan (Ugai, 2007). In fact, according to New Keynesian models this kind of policy should stimulate the aggregate demand even in the zero-bound environment as the current demand depends not only on the current interest rate but also on the future expected short-term rates and expected inflation.

The interest rate commitment was reiterated seventeen times within our sample and was always announced after the scheduled FOMC meetings. The dates of the FOMC meetings were known in advance to the market participants so as long as the economy was weak they were expecting the FOMC to reiterate the commitment. However, as the economic situation was gradually improving, market participants were reading with attention the Fed’s statement to see whether there would be a change in wording of the commitment, suggesting a future tightening. Given that only surprise interest rate commitment should have an impact on asset prices, we construct a surprise commitment dummy. It takes the value of 1 when the announcement came as a surprise, 0.5 when the financial markets were generally expecting the Fed to reiterate its commitment but there was some uncertainty about

last day). The surprise on these days is given by: $\Delta x_{s,t} = fff^1_{s,t} - fff^1_{s,t-1}$. Also, if the surprise occurs on the first day of the month, the relevant futures rate at time $t-1$ is fff^1 and the policy surprise is given by $\Delta x_{s,t} = fff^0_{s,t} - fff^1_{s,t-1}$. See Kuttner (2001) for details.

it, and 0 on the days when the commitment was fully anticipated. The measure of “surprise” part of the statement is based on articles from the Wall Street Journal and Reuters before and after the FOMC meetings. The details on the classification of each statement are included in Table 2.3.

B. Long-term Treasury bonds purchases

Another tool at the disposal of the central bank when the interest rates are close to zero is the outright purchase of long-term government securities. The effectiveness of this policy is based on the “portfolio balance effect”. By purchasing long-term securities, the central bank changes the composition of the portfolio of securities left in hands of private sector and therefore affects their yields. The theoretical basis for the effectiveness of open-market purchases of non standard assets were set by (Eggertsson and Woodford, 2003). Their representative-agent model predicts no effect for such operations on price level or output.⁵ However, the model of (Vayanos and Vila, 2009) based on preferred habitats of investors provides a theoretical basis for the portfolio balance effect. In their model, the interest rates of all maturities are determined through the interaction between risk-averse arbitrageurs and investor clienteles with preferences for specific maturities. In this framework the central bank purchases of long-term Treasuries can lower the long-term yields because they shorten the average maturity of government debt and therefore the duration risk held by market participants.

The first round of Quantitative easing was announced in Ben Bernanke’s speech in Austin on December 1, 2008 where he states that the Fed “could purchase longer-term Treasury securities in substantial quantities”. On December 16, 2008 the Federal Reserve announced that they were “evaluating the potential benefits of purchasing longer-term Treasury securities”. On January 28, 2009 they indicated that they were “prepared to purchase longer-term Treasury securities if evolving circumstances indicate that such transactions would be particularly effective in improving conditions in private credit markets”. On March 16, 2009 the FOMC decided to purchase up to 300 billion dollars of longer-term Treasury securities over the following six months. This

⁵Eggertsson and Woodford (2003) model requires 2 additional assumption that are likely not to hold during the crisis: (1) all investors can purchase and sell unlimited quantities of these assets, and (2) the assets being bought and sold are valued only for their pecuniary returns.

was the first time the Fed tried to change the relative supply of the long-term Treasury bonds since the “Operation Twist” in 1961.

Purchases of long-term bonds ended in October 2009 but were resumed the following year. On August 10, 2010 the Fed announced that they would reinvest principal payments from agency debt and agency mortgage-backed securities (which represented from \$250 to \$300 billion) into longer-term Treasury securities. Furthermore, on August 27, 2010 Ben Bernanke prepared markets for additional long-term asset purchases in his speech in Jackson Hole (Bernanke, 2010a).⁶ The FOMC meeting on September 21, 2010 confirmed the Fed’s intention to purchase longer-term bonds and the effective decision to buy \$600 billion of longer-term Treasury securities was taken on November 3, 2010. This second round of Treasury bonds purchases was called Quantitative Easing 2.

The Federal Reserve made most of the announcements concerning the purchases of longer-term securities after the scheduled FOMC meetings and the market participants could anticipate them. We construct surprise dummy based on the information included in specialized press articles (Wall Street Journal and Reuters). The dummy takes the value 1 when the announcements surprised financial markets. The surprise dummy is -1 on January 28, 2009 when the markets were expecting the Fed to take the stronger action.⁷ Table 2.4 presents the details about the statements.

C. Agency debt and MBS purchases

In addition to longer-term Treasury bonds, the Fed also purchased as a part of QE1 the debt and mortgage-backed securities of Fannie Mae and Freddie Mac. These agencies operated since 1968 as government sponsored enterprises (GSE). Their principal activity consisted in expanding the secondary market in mortgages. They were both privately owned but benefited from the “implicit” government guarantees which insured them favorable interest rates. In July 2008 Freddie Mac and Fannie Mae faced serious problems in meeting their obligations as the

⁶“A first option for providing additional monetary accommodation, if necessary, is to expand the Federal Reserve’s holdings of longer-term securities. (...) I believe that additional purchases of longer-term securities, should the FOMC choose to undertake them, would be effective in further easing financial conditions.” (Bernanke, 2010a). The speech in Jackson Hole was interpreted as a signal that renewed asset purchases are most likely. See “How the Fed Could Employ QE Again”, The Wall Street Journal Online, 28 August 2010 or “Roundup of reactions to Bernanke’s speech”, MarketWatch, 27 August 2010.

⁷See The Wall Street Journal, *Long-term Treasurys fall ahead of big issue, Fed stance*, 30 January 2009: “Longer-term issues remained under pressure after Wednesday’s selloff, driven by investors’ disappointment that the Federal Reserve didn’t signal a definite or imminent plan to buy long-term Treasuries.”

U.S. housing crisis worsened. In response to that, on Sunday July 13, 2008 the Secretary of the Treasury announced that the U.S. government would provide the backstop to GSE. On September 7, 2008 the Federal Housing Finance Agency (FHFA) put Fannie Mae and Freddie Mac under its conservatorship.

The surprise dummy, based on articles in Wall Street Journal and Reuters, takes the following values: 1 when the announcement is unexpected, 0.5 when it is expected but accompanied by the commitment to “expand the quantity of such purchases and the duration of the purchase program as conditions warrant” and is equal to zero when there was no announcement or when it was completely anticipated. Table 2.5 presents the details about the statements.

D. Liquidity facilities

Since the beginning of the crisis, the Fed established several liquidity facilities in order to restore the normal functioning of money markets. The additional funding sources were meant to encourage banks and non-banking institutions to lend more funds to each other and to bring down the borrowing costs. With the central bank liquidity at their disposal, the financial institutions have smaller incentive to hoard liquidity for precautionary reasons as they know they would be able to meet the unanticipated liquidity needs. On the other hand, the facilities should also bring down the default risk as the institutions' counter-parties would also benefit from the access to Fed's liquidity backstop.

In December 2007, the Fed introduced the Term Auction Facility (TAF) designed to auction term discount window loans to depository institutions. After the collapse of Bear Stearns, in March 2008 two facilities for primary dealers were launched: the Term Securities Lending Facility (TSLF) providing term loans of Treasury securities, and the Primary Dealer Credit Facility (PDCF) providing discount window loans. The failure of Lehman Brothers was followed by creation in September 2008 of the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF) designed to support money market funds and the market for ABCP. In October 2008, the Fed established the Money Market Investor Funding Facility (MMIFF) designed to provide liquidity to U.S. money market investors, and the Commercial Paper Funding Facility (CPFF) provid-

ing a liquidity backstop to U.S. issuers of commercial paper. Finally, in March 2009 in cooperation with the Treasury the Fed launched the Term Asset-Backed Securities Loan Facility (TALF) intended to revive the market for ABS.

Creation and expansion of liquidity facilities were announced on unscheduled meetings so we always consider them as surprises (see Table 2.6). The only exceptions are the days on which the time extension of the facilities was announced. Most of the facilities were announced to end on specific dates but the economy was still in the recession and the agents were expecting the Fed to extend the facilities that were about to expire.

E. Federal Reserve's rescue operations

During the crisis, the Fed rescued several financial institutions. Section 13(3) of the Federal Reserve Act allows the Fed to extend credit through discounts in “unusual and exigent circumstances” when a borrower is “unable to secure adequate credit accommodations from other banking institutions”. The main beneficiaries were Bear Stearns and AIG but we include in this category also the loans granted to Fannie Mae and Freddie Mac and the conversion of Morgan Stanley and Goldman Sachs into traditional bank holding companies. The description of each operation is presented in Table 2.7. As these events could not be anticipated by market participants, we attribute the dummy equal to 1 to each event.

- **Fiscal policy**

The severity of the crisis required numerous policy actions from both monetary and fiscal authorities. Therefore, in parallel to the Federal Reserve's monetary and credit easing, the U.S. government introduced several fiscal measures to offset the downturn. We take into account these announcements as it seems important to compare the impact of unconventional monetary policies to other policy actions. We divide fiscal policy actions into two categories: fiscal stimulus (Table 2.8) and government bailouts of individual troubled institutions (Table 2.9). Implementation of fiscal stimulus was multi-stage processes which required approval of the U.S. House of Representatives and the Senate. We include the announcements corresponding to all validation stages by the U.S. Congress and attribute them surprise dummy equal to 1 as these packages were controversial and there was uncertainty con-

cerning their approval. The dummy is equal to zero on the days of president's signature as at this stage the stimulus packages were certain to become a law.

During crisis, the U.S government provided also financial support to many troubled institutions to prevent them from failing. Market participants could not anticipate whether the government would bail out a particular financial institution so the dummy variable on the announcement day takes value equal to 1.

- **Failures of important financial institutions**

Government's bailouts and Fed's rescue operations were the response to critical situation of important financial institutions. Therefore, very often on a same day, an announcement about the Fed's and/or government's rescue operation was preceded by the bad news related to insolvency of a given financial institution. We include these events in our study (Table 2.10). The choice of bad news to be included is made based on several timelines of the crisis.⁸

2.4 Results

2.4.1 Libor-OIS spread

Some of the unconventional monetary policies were designed to ease the tensions on interbank market that appeared in August 2007 and intensified after the collapse of Lehman Brothers. Indeed, the generalized uncertainty concerning the health of banks' balance sheet made the banks unwilling to lend to each other. As a consequence, the Libor-OIS spread which is considered as a barometer of interbank market distress widened significantly.⁹

We test the impact of all announcements (conventional and unconventional monetary statements, fiscal policy and failures of important financial institutions) on the three-month Libor-OIS spread. We use the changes of the Libor-OIS spread as a dependent variable rather than the (potentially non stationary) level of the spread. As shown by

⁸See among others: 1.Federal Reserve Bank of St. Louis: <http://timeline.stlouisfed.org/index.cfm?p=timeline> 2.BBC News: <http://news.bbc.co.uk/2/hi/7521250.stm> 3.University of Iowa: <http://ebook.law.uiowa.edu/ebook/sites/default/files/FinancialCrisisTimeline.pdf>

⁹The London interbank offered rate (Libor), is an average interbank borrowing rate published daily by the British Bankers' Association (BBA). The overnight-indexed swap (OIS) rate represents market expectations of the funds rate over the future months. There is no exchange of principal and only the net difference in interest rates is paid at maturity, so there is very little default risk in the OIS market.

McAndrews et al. (2008), the changes of the spread are more appropriate if there is a possibility that the effect of liquidity facilities lasts several days after the event.

We estimate the following regression:

$$\Delta Sp_t = \alpha + \gamma \Delta x_t + \sum_{i=1}^I \varphi_i NC_{i,t} + \sum_{j=1}^J \beta_j F_{j,t} + L_t + \epsilon_t \quad (2.1)$$

where:

ΔSp_t is a 2-day change in 3-month Libor-OIS spread

Δx_t is a surprise daily change in official rate

$NC_{i,t}$ is a surprise component of unconventional monetary policy announcement i

$F_{j,t}$ is a surprise component of fiscal policy announcement j

L_t is a failure of important financial institution

ϵ_t is a stochastic error term

There is a timing issue related to Libor-OIS spread. The Libor rate is published at 11:00 a.m London time (06:00 ET) while the OIS rate is taken from Datastream and the last update is from 19:15 GMT (14:15 EST / 15:15 EDT). Therefore, most of the announcements on a given day were not taken into account by the Libor rate and some of them were not incorporated in the OIS rate either as they were made in the afternoon or in the evening. In particular, the FOMC statements announcing important unconventional monetary measures were issued at 14:15 ET (19:15 GMT or 20:15 GMT depending on the season of the year). In order to ensure that the markets had the possibility to react to all announcements we consider 2-day event window. The changes in the Libor-OIS spread are defined in a following way:

$$\Delta Sp_t = \Delta LIBOR_t - \Delta OIS_t$$

where:

$$\Delta LIBOR_t = LIBOR_{t+1} - LIBOR_{t-1}$$

$$\Delta OIS_t = OIS_{t+1} - OIS_{t-1}$$

Column (1) of Table 2.11 reports the estimation results. We find that the spread rises after the failures of important financial institutions by 29 basis points and is reduced following the government rescue operations by 24 basis points. Announcements related to TAF¹⁰ do not

¹⁰We distinguish TAF from other liquidity facilities to make reference to the discussion in the literature about the effectiveness of this facility.

affect the spread but those related to other liquidity facilities (TSLF, PDCF, AMLF, CPFF, MMIFF, AMLF) reduce the spread by 8 basis points.¹¹

Contrary to McAndrews et al. (2008) who also test the impact of the TAF announcements we do not find significant impact of the TAF on the Libor-OIS spread. Our results are different from those of McAndrews et al. (2008) as we study the whole period of crisis whereas their sample ends in April 2008. Also, we do not include the dummy -1 on 2008/02/01 but this observation does not change the overall results. Table 2.12 compares our results based on the whole sample (until December 31, 2010) with the results based only on the announcements covering the early period of the crisis (until April 24, 2008). While the TAF announcements had significant impact on the spread in the initial phase of the crisis, they become insignificant as the crisis worsened. These results suggest that in the later stage of the crisis the spread was driven by the default and not the liquidity risk as the results of Taylor and Williams (2009a) suggest.

2.4.2 Robustness checks

The positive and significant impact of failure of important financial institutions and the diminishing effect of government's recapitalizations and bailouts also suggest that the Libor-OIS spread is driven by the credit risk as these two types of events affect directly the probability of default. To control for the counterparty risk effect, we add as a proxy the credit default swaps (CDS) for the US banking sector into regression:

$$\Delta Sp_t = \alpha + \gamma \Delta x_t + \sum_{i=1}^I \varphi_i NC_{i,t} + \sum_{j=1}^J \beta_j F_{j,t} + L_t + \Delta cds_t + \epsilon_t \quad (2.2)$$

where:

Δcds_t is a 2-day change in 5-year US banks sector CDS index: $\Delta cds_t = cds_{t+1} - cds_{t-1}$

The results are presented in column (2) of Table 2.11. The coefficient of the credit risk proxy is, as expected, positive and significant. The coefficients of monetary and fiscal policies remain almost unchanged.

¹¹We obtain similar results after including as a control variable the lag of the LIBOR-OIS spread as in McAndrews et al. (2008).

The variations in the general uncertainty in the macroeconomy and financial markets may also drive the Libor-OIS spread. We add two indicators of risk and risk aversion: VIX¹² and Move¹³:

$$\Delta Sp_t = \alpha + \gamma \Delta x_t + \sum_{i=1}^I \varphi_i NC_{i,t} + \sum_{j=1}^J \beta_j F_{j,t} + L_t + \Delta rsk_t + \epsilon_t \quad (2.3)$$

where:

Δrsk_t is a 2-day change in VIX or MOVE index: $\Delta rsk_t = rsk_{t+1} - rsk_{t-1}$

Again, the coefficients for the proxies are positive and significant while other results do not change significantly (Table 2.11 column (3) and (4)). Finally, we include both credit risk proxy and the MOVE index (column (5) Table 2.11). All coefficients have magnitudes and significance level similar to those obtained earlier.

Libor-OIS spread is not the only appropriate indicator of the tensions on the interbank market. In order to confirm the robustness of our results we test the impact of unconventional measures on the alternative measures of money market distress: (1) spread between 3-month certificate of deposit and 3-month OIS; (2) spread between 3-month Libor and 3-month Treasury bond (TED spread); (3) 3-month Libor and Repos (Repurchase Agreement backed by Treasury securities).

As in previous regressions, we use daily data. The dependent variable are the previously described money market tension measures. The independent variables are conventional monetary policy announcements, unconventional monetary policy announcements, fiscal policy announcements, bad news about the health of important financial institutions, represented by dummies:

$$\Delta Sp_t^{alt} = \alpha + \gamma \Delta x_t + \sum_{i=1}^I \varphi_i NC_{i,t} + \sum_{j=1}^J \beta_j F_{j,t} + L_t + \epsilon_t \quad (2.4)$$

where:

ΔSp_t^{alt} is a 2-day change in (1) spread between 3-month certificate of deposit and 3-month OIS; (2) spread between 3-month Libor and 3-month Treasury bond (TED spread); (3) 3-month Libor and Repos (Repurchase Agreement backed by Treasury securities).

The results are reported in Table 2.13. The failures of important fi-

¹²VIX is a measure of the implied volatility of S&P 500 index options.

¹³MOVE is a measure of the implied volatility of Treasury market.

nancial institutions widened the spreads and the government recapitalizations and bailouts reduced them. These results are in line with the effects of these events on the Libor-OIS spread. The liquidity facilities on the other hand, have no significant impact on these spreads.

2.4.3 Long-term interest rates

In order to measure the impact of all policy announcements on long-term interest rates we estimate the following regression:

$$\Delta i_t = \alpha + \gamma \Delta x_t + \sum_{i=1}^I \varphi_i NC_{i,t} + \sum_{j=1}^J \beta_j F_{j,t} + L_t + \epsilon_t \quad (2.5)$$

where:

Δi_t is a daily change in 10-year nominal rates ($\Delta i_t = i_t - i_{t-1}$)

Δx_t is a surprise daily change in official rate

$NC_{i,t}$ is a surprise component of unconventional monetary policy announcement i

$F_{j,t}$ is a surprise component of fiscal policy announcement j

L_t is a failure of important financial institution

ϵ_t is a stochastic error term

In the first step we exclude the period of Quantitative Easing 2 and run the regression from January 4, 1999 until July 31, 2010. Regression results are reported in Table 2.14 column (1). The purchases of longer-term Treasuries lower the ten-year interest rates by 22 basis points and the purchases of long-term agency debt and MBS reduce it by 18 basis points. This result is not surprising given that Fannie Mae and Freddie Mac were nationalized in September 2008. In term of the risk portfolio they are very similar to long-term Treasury bonds. This evidence confirms the results of Hamilton and Wu (2012) and Gagnon et al. (2011) who also find that altering the maturity structure of publicly held Treasury debt lowered long-term interest rates in the United States during the QE1 period.

In the second step we include the QE2 period. Column (2) of Table 2.14 shows the regression results from from January 4, 1999 until December 31, 2010. The purchases of long-term Treasury bonds still reduce long-term interest rates but their impact is smaller (10 basis point compared to 22 before the QE2) and the coefficient is less significant.

Regression results from August 13, 2009¹⁴ until December 31, 2010 show that the QE2 bond purchases did not lower long-term nominal rates (Table 2.14 column (3)).

Some non-standard measures, interest rate commitment in particular, were intended to reduce medium-term interest rates. In order to evaluate the impact of unconventional monetary policies on the different parts of the yield curve, we orthogonalize the expectations of interest rates for different maturities. We separate the expectations by constructing three independent factors: Factor 1: changes in expectations of the current month interest rates; Factor 2: changes in expectations of the next year interest rates that are not already explained by the changes in current month expectations; Factor 3: changes in expectations of the interest rates over the next 10 years that are not explained by the changes in the 1-year expectations.

The factors are given by the following relations:

$$\Delta y_1 = F_1$$

$$\Delta y_{12} = \alpha_1 F_1 + F_2$$

$$\Delta y_{120} = \alpha_2 F_1 + \beta_1 F_2 + F_3$$

where:

Δy_1 - changes in Fed Funds Futures (monetary policy surprises as defined by Kuttner 2001)

Δy_{12} - changes in 1-year OIS

Δy_{120} - changes in 10-year nominal bond

We test the impact of all announcements on the second and the third factor before QE2 was introduced (Table 2.15 and Table 2.16 (1)).¹⁵ The results presented in Table 2.16 column (1) confirm that the QE1 purchases of long-term Treasuries and agency debt and MBS contribute to lowering medium and long-term interest rates (factor 3) by respectively 16 and 22 basis points.

Table 2.16 column (2) reports the results for the whole period including QE2. The purchases of agency bonds and MBS still reduce the third factor by 16 basis points but the impact of Treasury bonds purchases diminishes to 10 basis points and becomes less significant. In

¹⁴On August 12, 2009, the FOMC statement of that day announced that the full amount of bonds would be purchased by the end of October 2009.

¹⁵The sample period is from November 26, 2003 until July 31, 2010 as the data on OIS rates necessary to calculate factors were available from the end of 2003 only.

the period including only QE2 (August 13, 2009 - December 31, 2010), the impact of longer-term Treasury bonds purchases on the third factor is no longer significant (Table 2.16 column (3)).

Finally, we do not find evidence that interest rates commitment succeeded in lowering the expectations of interest rates from 1 month to 1 year (factor 2, Table 2.15).

2.4.4 Long-term inflation expectations

2.4.4.1 Some preliminary evidence on a change in inflation expectations

The expansion of the Federal Reserve's balance sheet was viewed by some observers as a threat to the Fed's commitment to low and stable inflation. At the same time, the worsening economic conditions, especially after the collapse of Lehman Brothers, raised concerns about future deflation. In order to get a preliminary view of the evolution of inflation expectations, we examine some market-based and survey-based indicators.

A. Spread between 10-year Treasury bonds and average Fed Funds

The term spread between 10-year Treasury bonds and average Fed Funds increased significantly since the crisis started in August 2007 (Figure 2.3). However, the term spread is a very crude measure of inflation expectations as it is also influenced by changes to expected real interest rate and term premia (inflation risk premium and real risk premium), which went up since the crisis started.

B. 10-year breakeven inflation compensation

In recent years, the market participants, analysts and policy makers were using the inflation-indexed financial instruments to gauge inflation expectations. One of them is the 10-year breakeven inflation compensation which is measured by the difference in yields between 10-year nominal and inflation-indexed bonds (10-year TIPS rate¹⁶). The 10-year breakeven inflation compensation rates declined strongly after the bankruptcy of Lehman Brothers. Although this might reflect deflationary expectations related to the worsening of economic situation, this preliminary evidence must be viewed with some caution.

¹⁶The U.S. Treasury issued Treasury inflation-protected securities (TIPS) for the first time in 1997. The coupon and principal payments of these bonds are indexed to the Consumer Price Index (CPI).

Inflation compensation is also affected by inflation risk premium and the differential liquidity premia between TIPS and nominal securities. It seems plausible that at the peak of the crisis the relative liquidity of TIPS and nominal bonds played important role in the inflation compensation evolution as the participants of the two markets are quite different. The main contributors in the TIPS market are institutional investors like pension funds or insurance companies with long-term liabilities who treat TIPS as buy-and-hold assets. The emergency rescue of AIG by the Fed led to some uncertainty concerning the financial health of insurance companies. The fire sales of their assets might explain the falling prices of TIPS. In contrast, the most important holders of the Treasury nominal bonds are primary dealers for whom nominal bonds play a role of hedging and trading vehicle. The sudden increase in uncertainty concerning the value of many financial instruments made the safe instruments like nominal bonds more attractive to investors. A strong increase in TIPS yields and a fall in nominal yields in autumn 2008 shown in Figure 2.4 suggest that there was indeed a disruption in relative liquidity in the two markets.

C. Forward inflation compensation

The 10-year breakeven inflation rate incorporates also short-term developments of inflation compensation. One way to measure specifically long-term expectations is to focus on the evolution of the far-ahead forward inflation compensation. Figure 2.5 shows 1-year forward inflation compensation from 9 to 10 years ahead. The far-ahead forward inflation has been changing over time and became particularly volatile in autumn 2008. In the beginning of 2009 it returns to its usual volatility. In January 2010 it starts declining but the trend reverses in August 2010 which coincides with the beginning of Quantitative Easing 2.

Figure 2.6 shows the 1-year nominal and real (TIPS) forward rates ending in 10 years. Both TIPS and nominal forward rates are very volatile in autumn 2008. The TIPS forward rate rises suddenly after Lehman Brother collapse but to a much smaller extent than spot 10-year TIPS rate. The nominal forward rate rises even more. This is in contrast with the nominal spot 10-year rate that declined significantly at the same time. This provides some tentative evidence that the disruption in TIPS liquidity relative to nominal bonds affected mostly short and medium term inflation compensation.

D. Survey-based inflation expectations

One way to measure the informative content of market-based inflation expectations is to compare them to survey-based inflation expectations. Figure 2.7 shows the University of Michigan survey of forward inflation expectations from 5 to 10 years. Figure 2.8 compares the market-based and the survey-based inflation expectations at the same horizon and shows that the survey-based forward inflation expectations were also unusually volatile during the peak of the current crisis.

2.4.4.2 Extracting the inflation expectations

In this study we use the market-based measure of long-run inflation expectations provided by Gürkaynak, Levin and Swanson (2010).¹⁷ It is based on the comparison between nominal and inflation-indexed Treasury securities (break-even inflation rates). More specifically, it is constructed as a difference between 1-year forward nominal rate ending in 10 years and 1-year forward TIPS rate ending in 10 years:

$$\pi_t^e = f_{1,t+9y}^n - f_{1,t+9y}^i$$

where:

π_t^e denotes the nine-year-ahead one-year forward inflation compensation.

$f_{1,t+9y}^n$ denotes the nine-year-ahead one-year forward nominal yield.

$f_{1,t+9y}^i$ denotes the nine-year-ahead one-year forward yield of inflation-indexed bond.

As we mentioned previously, the daily changes in forward inflation compensation rates may be driven not only by long-term inflation expectations ($IE_{1,t+9y}$) but also by forward inflation risk premium ($IP_{1,t+9y}$) or forward TIPS/nominal bonds liquidity premium ($LP_{1,t+9y}$):

$$\Delta\pi_t^e = \Delta IE_{1,t+9y} + \Delta IP_{1,t+9y} + LP_{1,t+9y}$$

Nevertheless, there are still two reasons for which breakeven inflation rates should be informative about expected inflation during the crisis. First, we use the forward inflation compensation rate (from 9 to 10 years ahead) and not the spot rate (from now to 10 years ahead). As discussed earlier, the relative TIPS liquidity worsened in autumn

¹⁷These data are updated periodically and available on Federal Reserve website: <http://www.federalreserve.gov/econresdata/researchdata.htm>

2008 but impacted mostly short and medium maturities. One-year far-ahead forward rates provide cleaner indication of long-horizon inflation expectations as they filter out the effects of short-term expectations. Second, the survey-based inflation expectations are also volatile during crisis which suggests that fluctuations in forward compensation can be also viewed as changes in expected inflation.

We test the impact of liquidity premium and inflation risk premium on far-ahead inflation compensation by estimating a regression model. Following Söderlind (2011), we use VIX to approximate the TIPS liquidity premium and bond options to account for inflation uncertainty. Moreover, we construct additional proxy for the differential liquidity premium between TIPS and nominal securities given that the nominal bonds' liquidity might also have changed during crisis (see Figure 2.4). The liquidity of each type of bond is approximated by its bid-ask spread. Therefore, the relative liquidity proxy is a difference between the bid-ask spread for TIPS and nominal bonds:

$$Bidask_t = Bidask_t^{TIPS} - Bidask_t^{Nom}$$

where:

$Bidask_t$ is a relative TIPS / nominal bonds liquidity proxy

$Bidask_t^{TIPS}$ is a bid-ask spread for TIPS

$Bidask_t^{Nom}$ is a bid-ask spread for nominal bonds

We estimate the following regressions:

$$\Delta\pi_t^e = \alpha_1 + \phi_1\Delta VIX_t + \gamma_1\Delta BO_t + \epsilon_t$$

$$\Delta\pi_t^e = \alpha_2 + \beta_1\Delta Bidask_t + \gamma_2\Delta BO_t + \epsilon_t$$

$$\Delta\pi_t^e = \alpha_3 + \phi_2\Delta VIX_t + \beta_2\Delta Bidask_t + \gamma_3\Delta BO_t + \epsilon_t$$

where:

$\Delta\pi_t^e$ is a daily change in one-year forward inflation from 9 to 10 years ahead ($\Delta\pi_t^e = \pi_t^e - \pi_{t-1}^e$)

ΔVIX_t is a daily change in the VIX index ($\Delta VIX_t = VIX_t - VIX_{t-1}$)

ΔBO_t is a daily change in options on 30-year bond futures ($\Delta BO_t = BO_t - BO_{t-1}$)

$\Delta Bidask_t$ is a daily change in relative TIPS / nominal bonds liquidity proxy ($\Delta Bidask_t = Bidask_t - Bidask_{t-1}$)

If these models are able to explain much in the movement of the far-ahead forward inflation compensation, we would expect the sign of ϕ_1 and ϕ_2 to be negative. In fact, systemic risk approximated by the

VIX index should increase the TIPS illiquidity and diminish inflation compensation. We would also expect the relative liquidity proxy to have negative sign as the bigger bid-ask spread for nominal bonds increases the inflation compensation and that the bigger TIPS bid-ask spread on the contrary diminishes it. On the other hand the inflation risk premium increases inflation compensation so the coefficient of this proxy should be positive.

Table 2.17 shows that both proxies for TIPS liquidity and relative liquidity are significant and have the expected sign. The proxy for inflation uncertainty, the implied bonds volatility, has a positive impact but is not significant. Therefore, we add only liquidity proxies into our regression model intended to measure the impact of unconventional monetary policies on long-term inflation expectations. Even though inflation expectations and inflation risk premium cannot be easily decomposed, they can be both associated with the capacity of the central bank to control inflation and it is not necessary to separate out these effects.

2.4.4.3 Unconventional monetary policy and fiscal policy announcements

As mentioned earlier, some of the unconventional monetary policies implemented by the Fed during crisis were perceived as inflationary. We evaluate the impact of these policies on long-term inflation expectations by measuring the response of far-ahead forward inflation compensation over the one-day period surrounding monetary policy actions and statements. We also measure its response to fiscal policy announcements in order to compare monetary and fiscal policy effect.

As in the case of long-term nominal rates we run the regression for two periods: including and excluding Quantitative Easing 2.

$$\Delta\pi_t^e = \alpha + \phi_1 \Delta VIX_t + \phi_2 \Delta Bidask_t + \gamma \Delta x_t + \sum_{i=1}^I \varphi_i NC_{i,t} + \sum_{j=1}^J \beta_j F_{j,t} + L_t + \epsilon_t \quad (2.6)$$

where:

$\Delta\pi_t^e$ is a daily change in one-year forward inflation from 9 to 10 years ahead ($\Delta\pi_t^e = \pi_t^e - \pi_{t-1}^e$)

ΔVIX_t is a daily change in the VIX index

$\Delta Bidask_t$ is a daily change in a relative liquidity proxy

Δx_t is a surprise daily change in official rate

$NC_{i,t}$ is a surprise component of unconventional monetary policy announcement i

$F_{j,t}$ is a surprise component of fiscal policy announcement j

L_t is a failure of important financial institution

ϵ_t is a stochastic error term

Table 2.18 column (1) reports the regression results for the period from January 4, 1999 to July 31, 2010, before QE2 was implemented. First of all, the failures of big financial institutions diminish long-term inflation expectations by 4 basis points. On the other hand, news related to Fed's rescue operations increases far-ahead forward inflation compensation by 5 basis points. Announcements related to other unconventional monetary policies and news about fiscal measures do not have significant impact on long-term inflation compensation. Fiscal stimulus announcements are only significant at 10% level at this stage.

In the second step we include in our regression the period of QE2 and estimate the sample from January 4, 1999 to December 31, 2010. Table 2.18 column (2) shows that the effect of the Fed's rescue operation is still positive and significant. However, this time the fiscal stimulus and purchases of longer-term Treasury bonds raise long-term inflation expectations by 6 basis points. The results for the period of QE2 (Table 2.18 column (3)) shows that QE2 longer-term Treasury purchases increase long-term inflation expectations by 7 basis points.

This result provides evidence that the second round of QE2 had quite different effect on long-term nominal interest rates and long-term inflation expectations than QE1. QE1 reduced long-term interest rates without raising inflation, whereas QE2 raised inflation expectations without diminishing long-term interest rates.

2.5 Conclusion

The implementation of unconventional monetary policies required the huge expansion of the Federal Reserve's balance sheet and the change of its composition. The non-standard monetary measures were implemented along with government fiscal stimulus and proved effective in many ways. The Fed's liquidity facilities other than TAF reduced to

some extent strains on the interbank markets (8 basis points) while the government's bailouts and recapitalizations diminished them by 24 basis points. The QE1 purchases of long-term Treasury and agency securities lowered long-term interest rates respectively by 18 and 22 basis points. On the other hand, long-term inflation expectations remained relatively stable before QE2 was introduced: the Fed's rescue operations were the only type of intervention that raised inflation expectations. The situation changed when QE2 was introduced. When the period of the second round of quantitative easing is included, the long-term Treasury bonds purchases and fiscal stimulus announcements raise long-term inflation expectations by 6 basis points.

The different effects of QE1 and QE2 on long-term interest rates and long-term inflation expectations are puzzling. The first round of quantitative easing lowered the long end of the yield curve and preserved the anchoring of long-run inflation expectations. The response of market participants to the second round of quantitative easing was different: long-term inflation expectations rose and long-term interest rates were not reduced. The different market reaction could be related to the perceived "permanent" character of QE2. Indeed, according to Auerbach and Obstfeld (2005) permanent monetary base expansion can have positive impact on prices. Moreover, the independence of the Fed with respect to Treasury might be more of an issue as the government bond purchases continued along with fiscal stimulus. The inflationary impact of rescue operations, often conducted with Treasury, seems to confirm the agents' sensibility to that question.

Even though QE1 and QE2 did not have the same impact on nominal long-term rates they both seem to lower real long-term rates as QE2 raised long-term inflation expectations. It appears that the overall effects of longer-term Treasury securities purchases is still an open question that would be pursued in further research.

2.6 Annexes

A1. Figures

Figure 2.1: Federal Reserve Assets

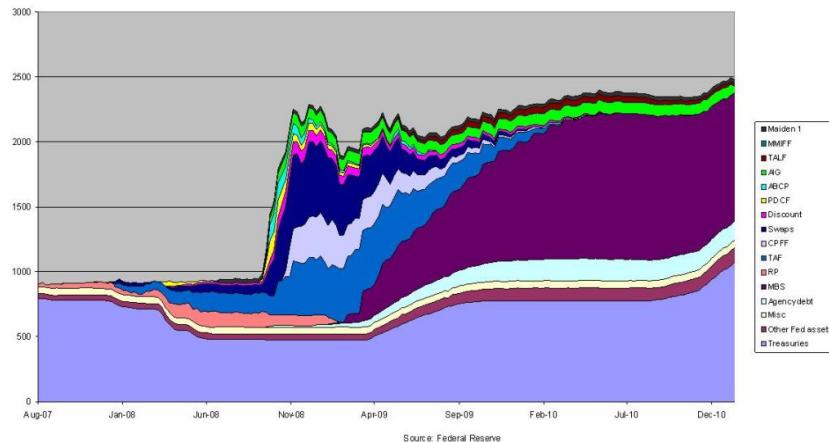


Figure 2.2: Monetary base and broader money aggregates

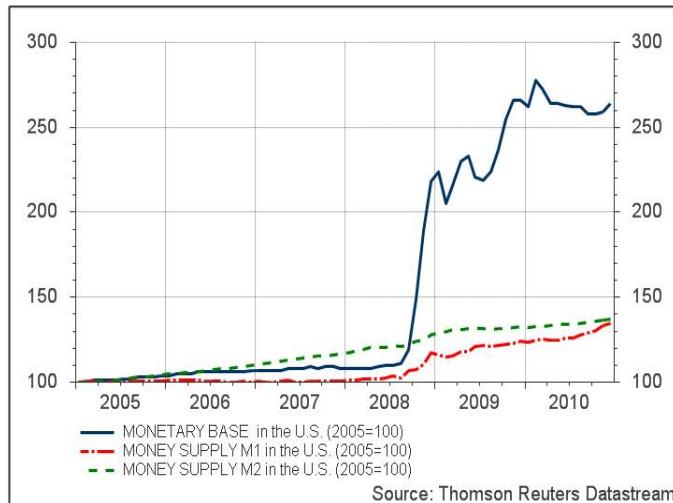


Figure 2.3: Term Spread: 10-year Treasury yield - average Fed Funds rate

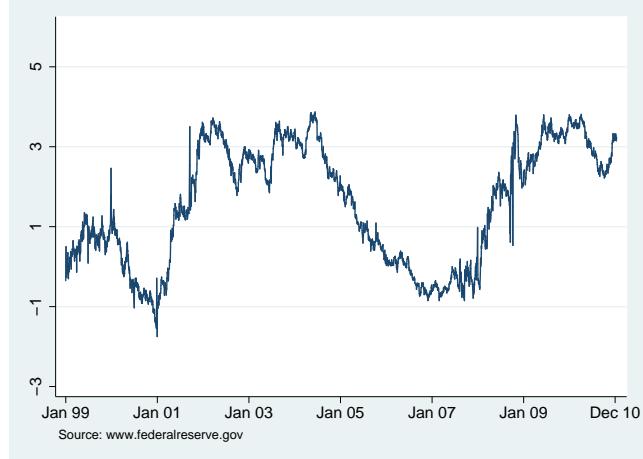


Figure 2.4: 10-year interest rates

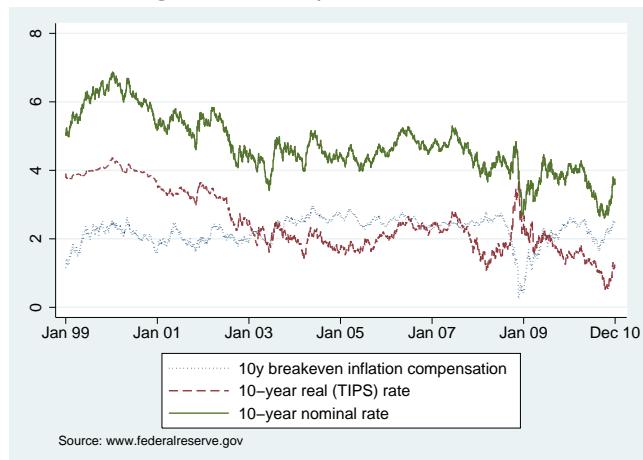


Figure 2.5: 1-year Forward Inflation Compensation ending in 10 years

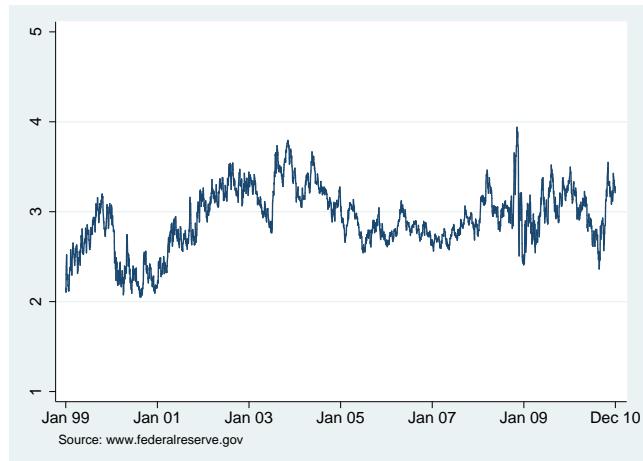


Figure 2.6: 1-year Forward Nominal and TIPS rates ending in 10 years

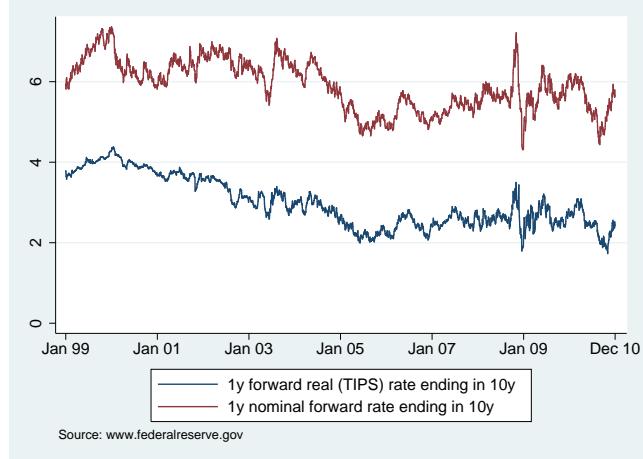


Figure 2.7: Survey: 5–10 Year Ahead Inflation Expectations

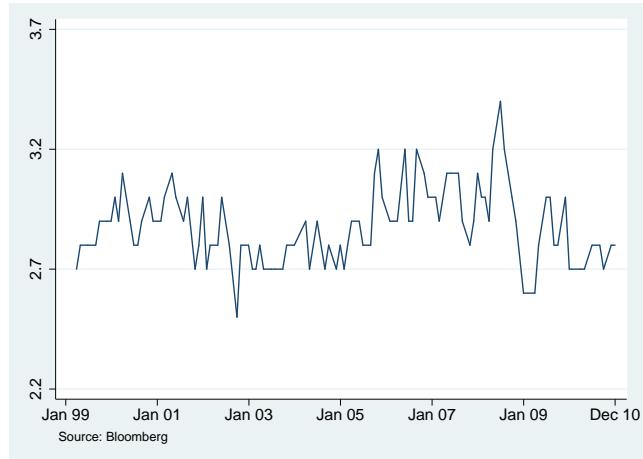
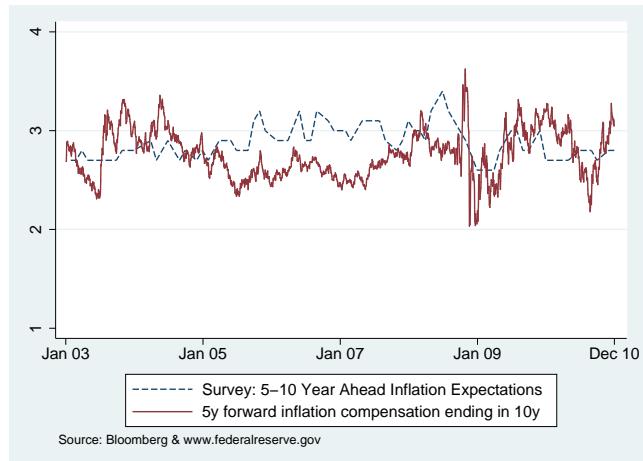


Figure 2.8: Forward Inflation Compensation and the Univ. of Michigan Survey



A2. Tables

Table 2.1: Dates of announcements - part 1

Date	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	Comment
20070809			1								BNP Paribas suspends 3 investment funds that invested in subprime mortgage market
20070918	1										FOMC statement
20071031	1										FOMC statement
20071206							1				U.S. President unveils the plan to ease pressure on the mortgage market
20071211	1										FOMC statement
20071212				1							TALF created
20080122	1										FOMC statement
20080129							1				Economic Stimulus Act of 2008 approved by the U.S. House of Representatives
20080130	1										FOMC statement
20080207							1				Economic Stimulus Act of 2008 approved by the Senate
20080213							1				U.S. President signs the Economic Stimulus Act of 2008
20080307				1							TAF increased to \$100 billion
20080311			1								TSLF created
20080314		1			1						Bear Stearns shares decline by 47%. Board authorizes the New York Fed to extend credit to JPMC to provide nonrecourse loan to Bear Stearns.
20080317			1	1	1						Bear Stearns bailed out. PDCC creation. Fed grants a loan to JPMC for acquiring Bear Stearns. (News on Sunday, September 16).
20080318	1										FOMC statement
20080430	1										FOMC statement
20080502				1							Expansion of the collateral in Schedule 2 TSLF auctions.
20080625	1										FOMC statement
20080711			1								Bad news about Government Sponsored Enterprises (GSE)/ talks about GSE nationalization
20080714			1		1	1					Indymac Bank's failure on July 11 in the evening (Friday). Treasury increases the credit line for Freddie Mac and Fannie Mae. Board grants Federal Reserve Bank of New York the authority to lend to Fannie Mae and Freddie Mac should such lending prove necessary. (News on Sunday, July 13).
20080723						1					The Housing and Economic Recovery Act passed by Congress
20080730				1			1				TAF maturity extended. U.S. President signs into law the Housing and Economic Recovery Act of 2008.
20080805	1										FOMC statement
20080908		1			1						Fannie Mae and Freddie Mac nationalized
20080915		1		1							Lehman Brothers collapsed. Important expansion of TSLF and PDCC: collateral, frequency, amount. (News on Sunday, September 14).
20080916	1		1								FOMC statement. Moody's and Standard and Poor's downgrades ratings on AIG credit.
20080917		1			1						Failure of AIG. Fed bailouts AIG (News on September 16, late in the evening).
20080919			1				1	1			AMLF created. Fed plans to buy short-term agency debt. Paulson financial rescue plan is unveiled (Emergency Economic Stabilization Act of 2008)
20080922					1						The Fed agrees to convert Morgan Stanley and Goldman Sachs Group into traditional bank holding companies and extends credit to their subsidiaries (News on Sunday, September 21)
20080925		1									Washington Mutual seized by the Federal Deposit Insurance Corporation
20080929		1		1	1						Emergency Economic Stabilization Act defeated 228-205 in the United States House of Representatives. Wachovia's failure. TAF expansion. Acquisition of Wachovia by Citigroup is facilitated by the FDIC and occurred with by the Fed and the Treasury.
20081001								1			Emergency Economic Stabilization Act of 2008 passed in Senate
20081003								1			U.S. President signs the Emergency Economic Stabilization Act

1* FOMC statements; 2* Interest rates commitment; 3* Failures of important institutions; 4* Liquidity facility creation; 5* Liquidity facility extension; 6* Fed's rescue operations; 7* Government's bailouts; 8* Purchases of agency debt/MBS; 9* Purchases of long-term Treasury securities; 10* Fiscal stimulus

Table 2.2: Dates of announcements - part 2

Date	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	Comment
20081006					1						TAF expansion.
20081007				1	1						CPFF creation. TAF expansion.
20081008	1										FOMC statement.
20081009			1			1					AIG's critical financial situation. FED lends to AIG late on October 8.
20081014									1		Secretary of the Treasury Paulson and President Bush separately announce revisions in the TARP
20081021				1							MMIFF creation
20081029	1										FOMC statement
20081110			1			1	1				AIG's critical financial situation. FED and Treasury lend to AIG
20081124			1				1				The US government agrees to rescue Citigroup after an attack by investors causes the stock price to plummet 60% over the last week.
20081125				1				1			TALF created. Fed announced purchases of agency debt and MBS.
20081202					1						Extension of PDCF, AMLF, TSLF up to April 30,2009
20081216	1	1						1	1		FOMC statement. Interest rate commitment. Fed repeats its intention to buy agency debt and MBS and stands ready to expand the purchase. Fed evaluates the benefits from purchasing longer-term Treasury securities.
20081230								1			Date of purchase of agency debt and agency MBS announced, the purchase plan will be realized in 6 months not several quarters as previously announced
20090116			1				1				Bailout of the Bank of America.
20090128	1	1						1	1		FOMC statement. Interest rate commitment. Fed repeats its intention to buy agency debt and MBS and stands ready to expand the purchase. Fed is prepared to buy longer-term Treasury securities.
20090203					1						Extension of facilities until October 30, 2009 instead of April 2009
20090210					1			1			Increase of the size of the TALF and expansion of the eligible asset classes. Fed repeats its intention to buy agency debt and MBS and stands ready to expand the purchase.
20090213									1		American Recovery and Reinvestment Act of 2009 passed in the House and in the Senate
20090217									1		American Recovery and Reinvestment Act of 2009 signed by President Obama
20090302			1			1	1				AIG reports the largest quarterly loss in US corporate history in the final three months of 2008. AIG receives rescue package from the US government. The Fed and the Federal Reserve Bank of New York plan to take up to a \$26 billion preferred interest in two AIG life insurance subsidiaries
20090303					1						TALF launched
20090318	1	1						1	1		FOMC statement. Interest rate commitment. Additional purchases of agency debt and MBS. Fed will buy longer-term Treasury securities.
20090429	1	1									FOMC statement. Interest rate commitment.
20090624	1	1									FOMC statement. Interest rate commitment.
20090812	1	1									FOMC statement. Interest rate commitment.
20090923	1	1									FOMC statement. Interest rate commitment.
20091104	1	1									FOMC statement. Interest rate commitment.
20091216	1	1									FOMC statement. Interest rate commitment.
20100127	1	1									FOMC statement. Interest rate commitment.
20100316	1	1									FOMC statement. Interest rate commitment.
20100428	1	1									FOMC statement. Interest rate commitment.
20100623	1	1									FOMC statement. Interest rate commitment.
20100810	1	1									FOMC statement. Interest rate commitment. The fed announces its plan to reinvest principal payments from agency debts and MBS in longer-term Treasury securities
20100827	1	1									Ben Bernanke's speech in which he said that the Fed could increase its purchases of Treasury securities.
20100921	1	1									FOMC statement. Interest rate commitment. The Fed stated that it "was prepared to provide additional accommodation if needed to support the economic recovery", displaying a bias towards easing that was absent from its last policy statement.
20101103	1	1									FOMC statement. Interest rate commitment. The pledge to buy an additional \$600 billion in long-term Treasury bonds by the middle of next year was slightly larger than the median expectation of \$500 billion in a Reuters poll.
20101214	1	1									FOMC statement. Interest rate commitment. The Fed reiterates its intention to purchase its \$600 billion of longer-term Treasury securities.

1* FOMC statements; 2* Interest rates commitment; 3* Failures of important institutions; 4* Liquidity facility creation; 5* Liquidity facility extension; 6* Fed's rescue operations; 7* Government's bailouts; 8* Purchases of agency debt/MBS; 9* Purchases of long-term Treasury securities; 10* Fiscal stimulus

Table 2.3: Interest rate commitment

Date	Dummy	Comments
20081216	1	The phrase “the Committee anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time” was introduced for the first time.
20090128	0	Economy had weakened and markets expected the Fed to reiterate the commitment.
20090318	1	Commitment expected but the Fed introduced of the term “for an extended period” perceived as stronger than the phrase “for some time”.
20090429	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20090624	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20090812	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20090923	0,5	Some economist expected the sign of “exit strategy”
20091104	0,5	Economy improved
20091216	0,5	Deceleration in the pace of jobs losses but experts do not think Fed will try to destabilize expectations
20100127	0	Hoenig dissent confirmed some experts expectations about the implementation of exit strategy
20100316	0,5	No one joint Hoenig as some feared, statement was reiterated
20100428	0,5	Some experts speculated the Fed would indicate a rate increase in the coming months in the statement
20100623	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20100810	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20100921	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20101103	0	Economy had weakened, markets expected the Fed to reiterate the commitment
20101214	0	Economy had weakened, markets expected the Fed to reiterate the commitment

Table 2.4: Longer-term Treasury bonds purchases

Date	Dummy	Comments
20081201	1	Ben Bernanke's speech in which he announces that the Fed “could purchase longer-term Treasury securities in substantial quantities”.
20081216	1	Fed evaluates the benefits from purchasing longer-term Treasury securities
20090128	-1	Fed is prepared to buy longer-term Treasury securities (market participants disappointed as they expected the decision about the purchases : -1)
20090318	1	Fed will buy \$300 billion of longer-term Treasury securities.
20100810	1	Fed will reinvest principal payments from agency debts and MBS in longer-term Treasury securities.
20100827	1	Ben Bernanke's speech in which he said that the Fed could increase its purchases of Treasury securities.
20100921	1	Fed stated that it “was prepared to provide additional accommodation if needed to support the economic recovery”, displaying a bias towards easing that was absent from its last policy statement.
20101103	1	The pledge to buy an additional \$600 billion in long-term Treasury bonds by the middle of next year was slightly larger than the median expectation of \$500 billion in a Reuters poll.

Table 2.5: Agency debt and MBS purchases

Date	Dummy	Comments
20081125	1	Fed announces purchases of GSE debt up to \$100 billion and MBS backed by GSE up to \$500 billion
20081216	0,5	Fed repeats it's intention to buy agency debt and MBS and stands ready to expand the purchase.
20081230	1	Date of purchase announced, the purchase plan will be realized in 6 months not several quarters as previously announced
20090128	0,5	Fed repeats it's intention to buy agency debt and MBS and stands ready to expand the purchase.
20090210	0,5	Fed repeats it's intention to buy agency debt and MBS and stands ready to expand the purchase
20090318	1	Additional 750 billion of agency MBS and additional purchase 100 \$billion of agency debt.

Table 2.6: Liquidity facilities

Date	Creation	Extension	Dummy	Comment
20071212	1	0	1	TAF created
20071221	1	0	1	Announce continuation of TAF
20080104	0	1	1	TAF's auction amount increased
20080307	0	1	1	TAF's auction amount increased
20080311	1	0	1	TSLF created
20080317	1	0	1	PDCF created
20080502	0	1	1	Expansion of the collateral in Schedule 2 TSLF auctions
20080730	0	1	1	TAF's maturity extended
20080915	0	1	1	Important expansion of TSLF and PDCF
20080919	1	0	1	AMLF created
20080929	0	1	1	TAF's expansion
20081006	0	1	1	TAF's expansion
20081007	1	1	1	CPFF created. TAF's expansion
20081021	1	0	1	MMIFF created
20081125	1	0	1	TALF's creation
20081202	0	1	0	Extension of PDCF, AMLF, TSLF up to April 30, 2009
20090107	0	1	1	Expansion of MMIFF
20090203	0	1	0	Extension of most facilities until October 30, 2009
20090210	0	1	1	Increase of the size of the TALF.
20090303	0	1	1	TALF launched
20090319	0	1	1	Expansion of TALF
20090501	0	1	1	Expansion of TALF
20090519	0	1	1	Expansion of TALF

Table 2.7: Federal Reserve's rescue operations

Date	Dummy	Comment
20080314	1	Federal Reserve Bank of NY extends credit to JPMC to provide nonrecourse loan to Bear Stearns.
20080317	1	Fed grants a loan to JPMC for acquiring Bear Stearns. (Announced on Sunday September 16).
20080714	1	Board grants Federal Reserve Bank of New York the authority to lend to Fannie Mae and Freddie Mac should such lending be necessary
20080917	1	Fed bailouts AIG (announced on September 16 late in the evening).
20080922	1	The U.S. Fed agreed to convert Morgan Stanley and Goldman Sachs Group into traditional bank holding companies and extended credit to their subsidiaries (announced on Sunday, September 21)
20081009	1	FED lends to AIG late on October 8.
20081110	1	FED and Treasury lend to AIG
20090302	1	The Fed and the Federal Reserve Bank of New York plan to take up to a \$26 billion preferred interest in two AIG life insurance subsidiaries.

Table 2.8: Fiscal stimulus announcements

Date	Dummy	Comment
20071206	1	President Bush unveils the plan to ease pressure on the mortgage market
20080129	1	Economic Stimulus Act of 2008 was passed by the U.S. House of Representatives
20080207	1	Economic Stimulus Act of 2008 approved by the Senate
20080213	0	President Bush signs the Economic Stimulus Act of 2008
20080723	1	The Housing and Economic Recovery Act was passed by Congress
20080728	1	The Housing and Economic Recovery Act was passed by Congress on Saturday July 26, 2008
20080730	0	President Bush signs into law the Housing and Economic Recovery Act of 2008.
20080919	1	Paulson financial rescue plan is unveiled (Emergency Economic Stabilization Act of 2008)
20081002	1	Emergency Economic Stabilization Act of 2008 passes in Senate late on October 1, 2008
20081003	1	Emergency Economic Stabilization Act was passed by the House of Representatives and President George W. Bush signed it into law.
20081014	1	Secretary of the Treasury Paulson and President Bush separately announced revisions in the TARP program
20090210	1	American Recovery and Reinvestment Act of 2009 passed in the Senate
20090213	1	American Recovery and Reinvestment Act of 2009 passed in the House and in the Senate late on Friday February 13, 2009
20090217	0	American Recovery and Reinvestment Act of 2009 signed by President Obama
20101215	1	Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010. The Senate passed the legislation on \$858 billion tax-cut plan
20101217	1	Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010. House voted 277-148 for final passage on the tax-cut agreement vote late on December 16, 2010 and President Obama signs it into law on December 17, 2010.

Table 2.9: Government's recapitalization

Date	Dummy	Comment
20080714	1	Treasury increases the credit line for Freddie Mac and Fannie Mae.
20080908	1	Fannie Mae and Freddie Mac placed into conservatorship of the FHFA
20080929	1	Acquisition of Wachovia by Citigroup is facilitated by the FDIC
20081110	1	FED and Treasury lend to AIG
20081124	1	The US government agrees to rescue Citigroup
20090116	1	Bailout of Bank of America.
20090302	1	AIG is to receive an extra \$30bn from the US government

Table 2.10: Failures of important financial institutions

Date	Dummy	Comment
20070809	1	BNP Paribas suspends three investment funds
20080314	1	Bear Stearns Shares decline by 47%.
20080317	1	Bear Stearn's failure. (news on September 16 SUNDAY).
20080711	1	Bad news about GSE/ talks about GSE' nationalization
20080714	1	Indymac Bank's failure on July 11 in the evening (Friday).
20080908	1	Fannie Mae and Freddie Mac nationalized
20080915	1	Lehman Brothers collapsed. Announcement made on September 14, SUNDAY.
20080916	1	Moody's and Standard and Poor's downgrade ratings on AIG's credit.
20080917	1	Failure of AIG (September 16 late in the evening).
20080925	1	Washington Mutual's failure
20080929	1	Emergency Economic Stabilization Act is defeated 228-205 in the House of Representatives + Wachovia's failure.
20081009	1	AIG's critical financial situation. FED lends to AIG late on October 8.
20081110	1	AIG's critical financial situation. FED and Treasury lend to AIG.
20081124	1	Citigroup stock price declined by 60% over the week
20090116	1	Bailout Bank of America.
20090302	1	AIG reports the largest quarterly loss in US corporate history of \$61.7bn in the final three months of 2008.

Table 2.11: Impact of monetary and fiscal announcements on 3-month Libor-OIS spread

3-month Libor-OIS spread	(1)	(2)	(3)	(4)	(5)
FOMC rate decisions	-0.04 [0.13]	-0.04 [0.13]	-0.01 [0.12]	-0.03 [0.13]	-0.02 [0.12]
Failures of financial institutions	0.29** [0.06]	0.29** [0.06]	0.27** [0.06]	0.28** [0.06]	0.27** [0.06]
Fed's rescue operations	-0.02 [0.07]	-0.02 [0.07]	-0.00 [0.07]	-0.02 [0.07]	-0.00 [0.06]
Agency debt and MBS	0.03 [0.05]	0.03 [0.05]	0.03 [0.05]	0.03 [0.05]	0.03 [0.04]
Long-term Treasury bonds	-0.02 [0.01]	-0.02 [0.01]	-0.00 [0.01]	-0.02 [0.01]	-0.01 [0.01]
Government's recapitalizations	-0.24** [0.07]	-0.23** [0.07]	-0.23** [0.07]	-0.24** [0.07]	-0.22** [0.07]
Fiscal stimulus	0.02 [0.04]	0.02 [0.04]	0.03 [0.04]	0.02 [0.04]	0.03 [0.04]
Interest rate commitment	-0.07 [0.04]	-0.06 [0.04]	-0.05 [0.04]	-0.06 [0.04]	-0.04 [0.04]
TAF creation and extensions	0.05 [0.05]	0.06 [0.05]	0.05 [0.04]	0.05 [0.05]	0.05 [0.05]
Other liquidity facilities	-0.08* [0.04]	-0.08* [0.04]	-0.08* [0.04]	-0.08* [0.04]	-0.08* [0.04]
CDS		0.08** [0.03]			0.06* [0.03]
MOVE			0.24** [0.07]		0.21** [0.07]
VIX				0.07** [0.02]	
Constant	-0.00 [0.00]	-0.00 [0.00]	-0.00 [0.00]	-0.00 [0.00]	-0.00 [0.00]
Observations	1,823	1,823	1,823	1,823	1,823

Newey West standard errors in brackets ** p<0.01, * p<0.05

Table 2.12: Impact of monetary and fiscal announcements on Libor-OIS spread in different phases of the crisis

3-month Libor-OIS spread	until Apr 24, 2008	until Dec 31, 2010
FOMC rate decisions	-0.03 [0.13]	-0.04 [0.13]
Failures of important financial institutions	0.29** [0.06]	0.29** [0.06]
Fed's rescue operations	-0.02 [0.07]	-0.02 [0.07]
Agency debt and MBS	0.02 [0.05]	0.03 [0.05]
Long-term Treasury bonds purchases	-0.02 [0.01]	-0.02 [0.01]
Government's recapitalizations/ bailouts	-0.23** [0.07]	-0.24** [0.07]
Fiscal stimulus	0.02 [0.04]	0.02 [0.04]
Interest rate commitment	-0.07 [0.04]	-0.07 [0.04]
TAF until 24 April 2008	-0.05** [0.02]	
TAF whole sample		0.05 [0.05]
Other liquidity facilities	-0.07 [0.04]	-0.08* [0.04]
Constant	-0.00 [0.00]	-0.00 [0.00]
Observations	1823	1823

Newey West standard errors in brackets ** p<0.01, * p<0.05

Table 2.13: Impact of monetary and fiscal announcements on alternative measures of money market tensions

	CD-OIS	Libor-Treasury	Libor-Repo
FOMC rate decisions	-0.18 [0.25]	-0.10 [0.23]	0.07 [0.21]
Failures of important financial institutions	0.62** [0.24]	0.50* [0.21]	0.26** [0.07]
Fed's rescue operations	0.09 [0.23]	-0.03 [0.14]	-0.03 [0.05]
Agency debt and MBS	0.09 [0.13]	0.02 [0.08]	0.07 [0.05]
Long-term Treasury bonds purchases	-0.02 [0.02]	-0.01 [0.03]	-0.03 [0.02]
Government's recapitalizations/ bailouts	-0.68* [0.32]	-0.43* [0.21]	-0.21** [0.08]
Fiscal stimulus	-0.03 [0.12]	-0.04 [0.08]	0.04 [0.05]
Interest rate commitment	-0.13 [0.08]	-0.10 [0.08]	-0.10 [0.06]
TAF creation and extensions	0.06 [0.08]	-0.06 [0.06]	0.08 [0.07]
Other liquidity facilities	-0.24 [0.13]	-0.09 [0.07]	-0.06 [0.06]
Constant	-0.00 [0.00]	-0.00 [0.00]	-0.00 [0.00]
Observations	1,823	1,823	1,823

Newey West standard errors in brackets ** p<0.01, * p<0.05

Table 2.14: Impact of monetary and fiscal announcements on 10-year nominal interest rates

10-year nominal rate	Before QE2	Including QE2	Only QE2
FOMC rate decisions	0.18** [0.05]	0.18** [0.05]	0.72 [0.77]
Failures of important financial institutions	-0.01 [0.06]	-0.01 [0.06]	
Fed's rescue operations	-0.01 [0.05]	-0.01 [0.05]	
Agency debt and MBS purchases	-0.18** [0.05]	-0.18** [0.06]	
Long-term Treasury bonds purchases	-0.22** [0.02]	-0.10* [0.05]	-0.01 [0.06]
Government's recapitalizations/ bailouts	-0.03 [0.07]	-0.03 [0.07]	
Fiscal stimulus	0.04 [0.03]	0.03 [0.03]	-0.02 [0.05]
Interest rate commitment	0.01 [0.04]	-0.06 [0.05]	0.04 [0.04]
Liquidity facilities	-0.01 [0.02]	-0.01 [0.02]	
Constant	0.00 [0.00]	0.00 [0.00]	-0.00 [0.00]
Observations	3013	3122	361
R-squared	0.05	0.04	0.00

Robust standard errors in brackets ** p<0.01, * p<0.05

Table 2.15: Impact of monetary and fiscal announcements on 2nd factor

Factor 2	Before QE2	Including QE2	Only QE2
Failures of important financial institutions	-0.07 [0.04]	-0.07 [0.04]	
Fed's rescue operations	0.01 [0.04]	0.01 [0.04]	
Agency debt and MBS purchases	-0.02 [0.02]	-0.02 [0.02]	
Long-term Treasury bonds purchases	0.00 [0.03]	0.00 [0.01]	0.00 [0.00]
Government's recapitalizations/ bailouts	0.05 [0.04]	0.05 [0.04]	
Fiscal stimulus	0.05 [0.03]	0.04 [0.02]	0.01 [0.01]
Interest rate commitment	0.02 [0.03]	0.02 [0.03]	-0.02 [0.01]
Liquidity facilities	-0.03 [0.02]	-0.03 [0.02]	
Constant	0.00 [0.00]	0.00 [0.00]	-0.00 [0.00]
Observations	1723	1832	361
R-squared	0.03	0.03	0.01

Robust standard errors in brackets ** p<0.01, * p<0.05

Table 2.16: Impact of monetary and fiscal announcements on 3rd factor

Factor 3	Before QE2	Including QE2	Only QE2
Failures of important financial institutions	0.03 [0.03]	0.03 [0.03]	
Fed's rescue operations	-0.01 [0.03]	-0.01 [0.03]	
Agency debt and MBS purchases	-0.16** [0.05]	-0.16** [0.06]	
Long-term Treasury bonds purchases	-0.22** [0.03]	-0.10* [0.05]	-0.01 [0.05]
Government's recapitalizations/ bailouts	-0.07 [0.05]	-0.07 [0.05]	
Fiscal stimulus	0.02 [0.02]	0.01 [0.02]	-0.02 [0.05]
Interest rate commitment	0.00 [0.04]	-0.07 [0.05]	0.05 [0.04]
Liquidity facilities	0.01 [0.02]	0.01 [0.02]	
Constant	0.00 [0.00]	0.00 [0.00]	-0.00 [0.00]
Observations	1722	1831	361
R-squared	0.07	0.05	0.00

Robust standard errors in brackets ** p<0.01, * p<0.05

Table 2.17: Impact of liquidity and inflation risk premium proxies on far-ahead forward inflation compensation

	(1)	(2)	(3)
Far-ahead forward inflation compensation			
VIX	-0.09*** [0.00]	-0.09*** [0.00]	
Bond options	0.13 [0.58]	0.04 [0.86]	0.12 [0.60]
Relative liquidity proxy		-0.30*** [0.00]	-0.30*** [0.00]
Constant	0.00 [0.82]	0.00 [0.93]	0.00 [0.81]
Observations	2,760	2,760	2,760
R-squared	0.01	0.01	0.02

Robust pval in brackets
*** p<0.01, ** p<0.05, * p<0.1

Table 2.18: Impact of monetary and fiscal announcements on inflation expectations

Far-ahead forward inflation compensation	Before QE2	Including QE2	Only QE2
VIX	-0.06** [0.02]	-0.07** [0.02]	-0.28** [0.04]
Relative liquidity proxy	-0.29** [0.07]	-0.29** [0.07]	-0.26 [0.56]
FOMC rate decisions	-0.06 [0.04]	-0.06 [0.04]	0.36 [0.49]
Failures of important financial institutions	-0.04* [0.02]	-0.04* [0.02]	
Fed's rescue operations	0.05* [0.03]	0.05* [0.03]	
Agency debt and MBS	0.04 [0.06]	0.04 [0.06]	
Long-term Treasury bonds purchases	0.03 [0.03]	0.06** [0.02]	0.07** [0.02]
Government's recapitalizations/ bailouts	-0.03 [0.04]	-0.03 [0.04]	
Fiscal stimulus	0.06 [0.03]	0.06* [0.03]	0.05 [0.05]
Interest rate commitment	0.00 [0.04]	-0.02 [0.05]	0.02 [0.03]
Liquidity facilities	-0.00 [0.02]	-0.00 [0.02]	
Constant	0.00 [0.00]	0.00 [0.00]	-0.00 [0.00]
Observations	2897	3001	346
R-squared	0.02	0.03	0.16

Robust standard errors in brackets ** p<0.01, * p<0.05

3 Have the ECB unconventional monetary policies lowered market borrowing costs for banks and governments?¹

3.1 Introduction

Since August 2007 severe financial market disruptions impaired traditional monetary transmission channels in the euro area. First, the 2007-2009 crisis increased uncertainty concerning the banks' balance-sheet health and paralyzed interbank lending. Second, the euro-area sovereign debt crisis led to the fragmentation of the single financial market and resulted in important differences in credit conditions across the member countries. The European Central Bank (ECB) faced a difficult task of restoring monetary transmission and maintaining price stability in these exceptional circumstances. However, the traditional monetary tool - the ECB main refinancing rate - did not affect other interest rates to the extent it used to before the crisis and the euro-area monetary authority had to design and implement unconventional monetary policies to attain its objectives.

The ECB operational framework was, on the one hand, modern and flexible enough to adjust promptly to new circumstances, especially with regard to liquidity provision to banks. On the other hand, the euro area construction limited the ECB's field of action. More particularly, sovereign debt purchases were strongly opposed by some member countries and the Federal Reserve-style quantitative easing was difficult to implement. Despite sometimes strong criticism, the ECB gradually introduced important unconventional measures: unlimited liquidity provision in euro and important foreign currencies, lengthening of the maturities of the loans, wider range of collateral accepted and outright purchases of private and government assets. This new

¹I would like to thank my supervisors Pierpaolo Benigno and Henri Sterdyniak for their guidance and valuable advice. This paper has also benefited from helpful discussions and suggestions from participants at CEPII/PSE Macro Finance Workshop and OFCE seminar. Any errors are mine.

policy toolkit was designed to “enhance the flow of credit above and beyond what could be achieved through policy interest rate reductions alone”².

The objective of this chapter is to provide an empirical evidence on the impact of the ECB non-standard measures on the market borrowing costs for banks and governments. This question is motivated by the importance of banks in financing the euro-area economy and by the crucial role that long-term government refinancing plays in the ongoing euro-area crisis. There is a rapidly growing literature about the effectiveness of alternative monetary policies in the U.S. and the U.K. but the empirical evidence about the effects of non-orthodox measures in the euro area is still relatively scarce. The impact on macroeconomic variables was studied by Peersman (2011) and Gambacorta et al. (2012) who showed that the ECB unconventional monetary policies increased output and inflation. Beirne et al. (2011) evaluated via an event study the impact of the first covered bond purchasing program and found that it was effective in lowering covered bond spreads. The impact of the ECB unconventional policies on money market spreads is much less clear and the existing studies are skeptical about the effectiveness of exceptional liquidity measures in increasing interbank lending (Brunetti et al. 2011, Angelini et al. 2011).

To our best knowledge this study is the first one to evaluate the effectiveness of all ECB unconventional monetary policies implemented between 2007 and 2012 on bank and government borrowing costs. Specifically, we employ event-based regression to measure the impact of the ECB announcements on money market spreads, covered bond spreads and sovereign bond spreads in the euro-area. Our methodology allows for the simultaneous evaluation and comparison of the effects of the non-orthodox measures. First, we make a timeline of unconventional monetary policy announcements and classify them into six main categories: 1) fixed-rate full-allotment procedure (FRFA), 2) three-year refinancing operations (3y LTRO), 3) collateral easing and 4) covered bond purchase programmes (CBPP1 and CBPP2), 5) long-term sovereign bond purchases (Securities Markets Programme, SMP) and 6) short-term sovereign bond purchases (Outright Mone-

²Trichet (2009).

tary Transactions, OMT). We also consider conventional interest rate policy and less important liquidity measures to ensure that the effect of main unconventional policies is not due to other announcements, sometimes made on the same day. Given the exceptional circumstances during the sovereign debt crisis we also take into account the European Financial Stability Facility / European Stability Mechanism announcements and add a sovereign crisis dummy for the peaks of the crisis. In order to put the ECB measures into perspective, we also include quantitative easing announcements in the U.S. and the U.K.

The results show that among the ECB unconventional measures, long-term sovereign bond purchases (SMP) proved to be the most effective in lowering longer-term borrowing costs for both banks and governments. The effects are the most important for the euro-area sovereign spreads and range from 35 basis points (Italy) to 476 basis points (Greece). As a comparison, we show that the U.S. and U.K. sovereign spreads also fell following the sovereign bond purchases announced by the Fed and the Bank of England but the magnitude of the effect was much smaller: respectively 5 and 9 basis points. The strong impact in the euro area suggests that the central bank intervention in sovereign market is particularly effective when the sovereign risk is important. The SMP also reduced longer-term bank refinancing costs, namely covered bond spreads, as the smaller country default risk improves the financial standing of the country financial institutions. The second bond purchasing program, OMT, had a similar impact on borrowing conditions as SMP: it diminished, albeit to smaller extent, sovereign spreads and covered bond spreads, especially in periphery euro area countries. As far as covered bond purchase programs are concerned, they reduced the spreads in all markets studied: covered bond spreads, sovereign bond spreads and to some extent the money market spreads. Finally, among the exceptional liquidity provisions, the 3-year refinancing operations (3y LTRO) were the only measure that succeeded in reducing bank refinancing costs and its impact was particularly strong in money market.

The reminder of this chapter is organized as follows. The ECB unconventional monetary policy announcements, their objectives and theoretical basis for their effectiveness are described in section 3.2. Methodology and data are presented in section 3.3. In section 3.4 we

estimate the impact of the announcements on money market, covered bonds and sovereigns bonds spreads. Section 3.5 concludes.

3.2 Unconventional monetary policies implemented by the ECB

The ECB unconventional monetary policies implemented by the ECB can be regrouped into three categories: 3.2.1) exceptional liquidity measures, 3.2.2) purchases of assets and 3.2.3) collateral easing. In this section we present these measures, their theoretical foundations and the objectives they were meant to attain.

3.2.1 Liquidity provisions

Since the beginning of the subprime crisis the ECB reacted very promptly to the tensions on the interbank market. The operational framework of the ECB was already quite flexible compared to other central banks: the ECB accepted a wide range of collateral and provided liquidity to large number of counterparties. However, the regular liquidity tools failed to calm down unprecedented interbank tensions due to global economic crisis and the euro-area sovereign debt crisis (Figure 3.1). Therefore, the ECB implemented several additional liquidity measures that we define here as unconventional since they go beyond the regular framework of the open market operations.³

The main objective of exceptional liquidity provisions was to restore the smooth functioning of interbank markets as this aspect was crucial for extending credit to firms and households.⁴ The ECB made clear all along the crisis that monetary policy stance and liquidity programs were two different things, and the latter were merely supposed to normalize euro money markets and improve the monetary transmission.

The exceptional liquidity measures may be effective in stabilizing interbank market for several reasons. The liquidity shortage has a negative impact on financial institution lending capabilities and may result in

³The regular open market operations at the ECB include: 1) Main refinancing operations (MRO) with a frequency and maturity of one week. 2) Longer-term refinancing operations (LTRO) with a monthly frequency and a maturity of three months. 3) Fine-tuning operations designed to smooth the effects on interest rates caused by unexpected liquidity fluctuations. 4) Structural operations carried out by the Eurosystem through reverse transactions, outright transactions and issuance of debt certificates.

⁴Draghi (2008): “Restoring the smooth functioning of the interbank markets globally and within the euro area is a precondition to ensure the stability of credit flows to households and firms, thereby minimizing the real impact of the financial turmoil”.

credit crunch. Liquidity-constrained banks excessively hoard liquidity for precautionary reasons and proceed to fire sales of assets affecting negatively their prices. The ECB unconventional measures by ensuring funding liquidity diminish these adverse effects. They also reduce the banks' uncertainty with respect to funding liquidity of other market participants and therefore diminish counterparty risk premiums.

Furthermore, the excess liquidity provisions can affect the economy via portfolio rebalancing effect (Meltzer, 1995; Tobin, 1982) when money and other financial assets are not perfect substitutes. Market participants faced with increased money supply want to trade money for non-money assets which increases prices of non-monetary assets and reduces their yields. The ECB excess liquidity might have encouraged banks to purchase sovereign and corporate bonds as they would realize interest-rate gains with these transactions. The imperfect substitutability of assets, in general equilibrium framework, can in particular be linked to a difference in liquidity between money and other assets. Increase in money supply could reduce the liquidity premium and stimulate investment (Kiyotaki and Moore, 2012) and reduce long-term interest rates (Andres et al., 2004).

However, the ECB unlimited liquidity provision can also have perverse effects on the money market. It might contribute to “crowding out” of private liquidity and the effective substitution of the ECB for the interbank market trades. The central bank interventions can therefore create greater uncertainty in the interbank market rather than enhancing liquidity as intended (see empirical study of Brunetti et al., 2011). The important functions of interbank transactions such as information aggregation, price discovery and peer monitoring are reduced if unlimited liquidity is available from the central bank. Indeed, Heider et al. (2009) theoretical model shows that in case of high counterparty risk and informational asymmetry, the central bank liquidity injections result in liquidity hoarding and finally contribute to the greater distress of the money markets.

In this chapter, we measure the impact of the strongest ECB liquidity innovations: announcements of the fixed-rate full-allotment procedure (FRFA) and the 3-year refinancing operations (3y LTRO). However, since 2007 the ECB has implemented other exceptional liquidity mea-

sures: gradual lengthening of LTRO maturity up to 1 year and refinancing operations in foreign currencies. We take into account these innovations even though they are closer to conventional liquidity provisions. In fact, some of these liquidity announcements were made on the same day as the important measures that we focus on and we want to separate their effects.

3.2.1.1 Fixed-rate full-allotment (FRFA)

The fixed-rate procedure with full allotment (FRFA) was an important part of the ECB's non-standard toolbox. Traditionally, the open market operations were conducted through variable-rate tenders. Under the new procedure, the banks could satisfy all their liquidity needs at the interest rate specified in advance (the interest rate on the main refinancing operation). By ensuring banks' continued access to liquidity the ECB intended to offset liquidity risk in the market. The fixed tenders for the main refinancing operations (MROs), without full allotment, existed in the beginning of the Eurosystem (01/1999 - 06/2000) but were quickly abandoned as the banks were overbidding. When the subprime crisis started, the ECB conducted two fine tuning operations (FTOs) as a fixed-rate tenders with full allotment but it is only after the Lehman Brothers collapsed that it introduced the fixed-rate full-allotment procedure for all their open market operations and for the foreign liquidity swaps (Table 3.1). First, late on October 8, 2008, the ECB announced that all weekly MROs would be carried out through a fixed-rate tender procedure with full allotment rather than through a variable rate tender format used before. On October 13, 2008 it decided to provide unlimited dollar funding in coordinated action with the Fed. Two days later, on October 15, 2008 the ECB decided to conduct its longer-term refinancing operations (LTROs) on a FRFA basis as well. The ECB decided to return to variable-rate tender procedure in the regular 3-month LTROs in March 2010. However, the Greek debt crisis forced it to resume a FRFA procedure in the regular LTROs in May 2010.

3.2.1.2 Three-year refinancing operations (3-year LTRO)

On December 8, 2011, the ECB took an unprecedented measure to conduct two three-year refinancing operations (3y LTRO) with full allotment, with the interest rate fixed at the average rate of the MROs over the life of the operation. The first 3y LTRO was offered on December 21, 2011 and the second on February 29, 2012. The banks borrowed more than €1 trillion which covered their immediate funding needs and prevent them from selling assets and cutting some types of lending (Aglietta et al. 2012). The announcement of the 3y LTRO is incomparable to other liquidity measures and created a real surprise on the markets. The three-year loans are quite exceptional in the history of central banking as they extend the central bank intermediation from money markets to capital markets. Taking into consideration the special character of this measure and the surprise it created we separate this announcement from the other liquidity measures.

3.2.1.3 Longer maturities of the refinancing operations in euros

Soon after the beginning of the subprime crisis, the ECB increased the liquidity provisions through the longer-term refinancing operations (LTROs). The LTROs are liquidity-providing reverse transactions that are regularly conducted with a monthly frequency and a maturity of three months. The ECB does not usually fix the rate of these operations but let the banks participating in auction define it in a variable-rate tender. The LTROs dates are known in advance as the ECB announces them in an indicative calendar. However, during the crisis the ECB announced supplementary LTROs and some of them of maturity exceeding three months. In this chapter, we consider the announcements of liquidity provisions at maturities longer than three months as unconventional in line with Trichet (2009)'s classification (for the dates and description of the announcements see Table 3.2).⁵

The ECB first lengthened the maturity of the supplementary LTROs to six months after the Bear Sterns collapsed in March 2008, to encourage banks in the euro area to lend to one another for longer periods. The 6-month operations were seen as significant because it was the

⁵ As a robustness check, we add to this category all supplementary liquidity measures which are even closer to regular liquidity operations: supplementary 3-month LTROs announcements and special-term refinancing operations (1 month) but it does not change significantly the results.

first time the central bank has departed from its standard three-month funding operations. The maturity of loans was further extended to one year in May 2009. As the economy was recovering, the supplementary liquidity measures were to be wound up. However, the outburst of the Greek debt crisis in spring 2010 forced the ECB to resume the supplementary LTROs and to increase again their maturity to ensure that commercial banks get the crucial funding. Indeed, the money markets started to freeze again as the exposure to risky sovereign debt made banks wary of lending to one another.

3.2.1.4 Liquidity in foreign currencies

Along with the liquidity provisions in euro, the ECB furnished to banks liquidity in foreign currencies thanks to the currency swaps established with other central banks. Within these agreements, reversible in a later date, the ECB exchanged euros against dollars, the Swiss franc and the British pounds and used the foreign currency to lend to euro-area financial institutions. The foreign currency swaps, just as supplementary euro liquidity provisions, were implemented in both subprime and sovereign debt crisis (See Table 3.3).

When the subprime crisis started and a chain of defaults occurred on the U.S. subprime mortgage markets, the euro-area banks had difficulties to renew their funding in U.S. dollars. In December 2007 the ECB announced the foreign currency swaps with the Fed to help money markets function more smoothly. The terms and amounts of the swaps were regularly expanded and since October 2008 the liquidity in dollars was distributed to banks at FRFA basis. Progressively, the ECB concluded swap arrangements also with the Swiss National Bank (SNB) to provide the Swiss franc to euro-area financial institutions.

The ECB closed the swap lines with the Fed on February 1, 2010 but was obliged to resume them in May 2010. At the onset of the European crisis, foreign lenders retreated out as they feared that the euro-area financial institutions were holding too much bad sovereign debt and may be insolvent. As the crisis worsened, the arrangements were subsequently extended. In addition to Fed and SNB swap lines, the arrangements were also made with the Bank of England (BOE) in December 2010 in order to provide liquidity in sterling to Irish banks

and limit the problems faced by the Irish banking system.

3.2.2 Purchases of assets

In a period of financial distress, the central bank can modify the composition of its assets by purchasing the securities that suffer from temporary liquidity problems or are undervalued by financial markets. This policy is sometimes called “credit easing”. The purchases can be sterilized by disposal of the other central bank assets (“pure credit easing”) or be a part of the central bank balance-sheet expansion (“quantitative easing”).

The effectiveness of credit easing is based on the “portfolio rebalancing effect”: when the assets are not perfect substitutes, reducing the quantity of selected assets available for private investors increases their prices and diminishes yields by suppressing the risk premia (Bernanke, 2010a). The portfolio rebalancing effect is controversial from a theoretical point of view. A representative-agent model of Eggertsson and Woodford (2003) predicts no effect for such operations on price level or output. However, this result holds only under following assumptions: (1) all investors can purchase and sell unlimited quantities of these assets, and (2) the assets being bought and sold are valued only for their pecuniary returns. The first assumption is likely not to hold during crisis as there exist binding constraints on participation in some markets. One example of general equilibrium analysis in which these constraints exist and credit easing affects asset prices is Cúrdia and Woodford (2011). As for the second assumption, Krishnamurthy and Vissing-Jorgensen (2011) show that US government debt for example possesses non-pecuniary qualities that are valued by the financial sector above their pure pecuniary returns given that Treasuries are often required as collateral in repo transactions.⁶

Furthermore, replacing a representative agent with no preference between markets and assets by heterogeneous agents can also provide rationale for central bank asset purchasing. In the preferred-habitats model of Vayanos and Vila (2009) the interest rates of all maturities are determined through the interaction between risk-averse arbitrageurs and investor clienteles with preferences for specific maturities.

⁶It should be noted however, that government bond purchases by central banks diminish the availability of these desirable assets and can be welfare reducing.

In this framework, the central bank purchases of long-term Treasuries can lower the long-term yields because they create a “scarcity effect” that arbitrageurs cannot eliminate. Moreover, the purchases can be effective as they shorten the average maturity of government debt and therefore the duration risk held by arbitrageurs.

In this chapter we investigate the effects of the ECB purchases of covered bonds and euro-area sovereign debt. These assets are more risky than government bonds considered in Vayanos and Vila (2009) and the duration risk is not the only one that the central bank takes on its balance sheet. By purchasing above mentioned assets the ECB also accepts the liquidity and default risk that private investors do not want to hold and it replaces it with riskfree reserves. Private investors would ask for smaller liquidity compensation when buying covered or sovereign bonds knowing that they would be able to sell the asset easily to the ECB.

Moreover, the sovereign debt crisis in Europe increased the default risk in the sovereign bond markets. Market participants started to price in a high probability of sovereign default and even the high probability that some member state would exit the euro area. Such projections cut off these countries’ access to market refinancing or made it extremely costly leading to “self-fulfilling” prophecy and to the outcome that investors were concerned about. By purchasing government bonds, and indirectly securing the sovereign debt, the ECB intended to prevent this “bad equilibrium” outcome.

There exists another channel of central bank asset purchases which instead of reducing risk premia has an impact on private sector’s expectations of the future monetary policy (“signaling effect”). Accumulation of risky asset on central bank balance sheet associated with important balance sheet expansion can be understood by financial markets as a signal that the monetary easing will continue longer than previously expected. Indeed, raising interest rates in these circumstances would expose the central bank to capital losses on the assets it holds. In this chapter however, we focus on the ECB impact on risk premia rather than on agents expectations of future monetary policy given that the ECB objective was to restore homogeneous credit conditions throughout the euro area, but not necessarily to ease credit conditions in aggregate (Cœuré, 2012). Increased risk premia

(spreads) on certain markets in the euro area were the reflection of these divergent credit conditions.

3.2.2.1 Sovereign bond purchases (SMP and OMT)

The Greek sovereign debt in Spring 2010 triggered a fire selling of some euro-area government bonds. The ECB launched on May 9, 2010 the Securities Market Programme (SMP) as a part of European Union efforts to stabilize the euro.⁷ The program was designed to purchase sovereign bonds and therefore “ensure depth and liquidity in those market segments which are dysfunctional”.⁸ This was the first time the ECB and its constituent central banks bought public debt and the SMP was from the start a source of division within the ECB. The critics said that the ECB was overstepping its mandate by buying public debt in secondary markets and that the bond purchases would increase the inflationary pressures as well as undermine the ECB credibility. However, the ECB insisted that the SMP was temporary and merely aimed at improving the transmission of the monetary policy. In order to distinguish the SMP from the U.S.-style quantitative easing and to ensure that the monetary policy stance is not affected, the ECB decided to sterilize these purchases via specific operations designed to re-absorb the injected liquidity.⁹ Another notable difference with the Fed sovereign bond purchases, is that the ECB gave no details on how much it could spend or how long it intended the program to last. It did not deliver precise quantities of bonds bought from specific countries neither. The purchases stopped unofficially in January 2011 but the intensity of euro crisis and the risk of contagion to Italy and Spain made the ECB resume the program. After an emergency meeting on Sunday August 7, 2011 the ECB announced they would actively purchase euro-area debt. Since the start of the program, the ECB bought a total 219.5 billion euros of euro area government bonds (see Figure 3.2).

The euro-area debt crisis continued in the beginning of 2012 as the critical financial standing of Spanish banks was revealed. The concerns about their solvency and *in fine* solvency of the Spanish government

⁷On the same day the EFSF was established.

⁸“ECB decides on measures to address severe tensions in financial markets”, ECB Press Release, 10 May 2010.

⁹The sterilization of SMP operation is questionable however, given that the banks had unlimited access to the central bank liquidity and the ECB had no longer control over the monetary base.

made the sovereign yields in the euro area periphery increase rapidly as market participants were pricing in the possibility of some countries leaving the monetary union. As a response, the ECB President Mario Draghi announced in July 2012 that the central bank would do “whatever it takes to save euro”.¹⁰ On September 6, 2012, the ECB announced the sovereign bond purchasing program: Outright Monetary Transactions (OMT) and at the same time officially terminated SMP. The objective of the new program, just as the objective of SMP, was to repair monetary policy transmission mechanism and restore homogeneous credit conditions throughout the euro area. More precisely, the purchases of the euro-area periphery sovereign debt was intended to reduce the risk premia related to fears of the reversibility of the euro. Despite the shared objective, OMT was different to SMP in several aspects. First, the maximum maturity was set to 3 years whereas the SMP concerned the longer-term bonds. Second, there was a conditionality attached to participating in OMT: the ECB would only purchase sovereign debt of a given country if its government complies with a full or precautionary macroeconomic adjustment program set by the European Financial Stability Facility (EFSF) or the European Stability Mechanism (ESM). Third, the ECB decided to forgo its seniority status with respect to private creditors. Finally, once the country meets the access conditions, the ECB would intervene without limits whereas SMP was always presented as “temporary” and “limited” which was hardly reassuring for investors.¹¹ OMT was intended as pure “credit easing” meaning that the purchases of bonds would just change the assets composition of the central banks but not increase the overall monetary base.¹²

3.2.2.2 Covered bond purchases (CBPP1 and CBPP2)

Covered bonds are securities issued by credit institutions to assure their medium and long-term refinancing. They are collateralized by a dedicated pool of loans, typically mortgage loans and public-sector loans, which comply with a minimum legal standard and remain on the

¹⁰Draghi (2012).

¹¹Introductory statement to the ECB press conference, November 3, 2011 available at: <http://www.ecb.int/press/pressconf/2011/html/is111103.en.html>

¹²As in the case of SMP, the sterilization operations seem mostly symbolic as the fixed-rate full-allotment procedure in all main refinancing operations leaves the control of monetary base in hands of banks participating in these operations.

lender's balance sheet. This high quality collateral allows the credit institution issuing bonds that have higher credit rating than its own rating. They are seen as safer than other bank bonds, because they give investors a claim on the the issuing credit institution itself and on the the cover pool of collateral as well. This "dual recourse" feature of covered bonds make them also more attractive and more liquid than the ABS market. Unlike in the standard securitization process, the issuer of covered bonds keeps the ownership of the pooled mortgages and loans and ensures that they are at all times sufficient to satisfy the claims of bondholders.

These specific features of covered bonds contributed to the development of their market. A relatively low risk and the return higher than government bonds makes them highly attractive in the eyes of investors. At the end of 2007 it was the most important privately issued bond segment in Europe's capital markets (ECB, 2008). The relative safety of covered bonds contributed to its resilience to the financial turmoil that started in August 2007. However, after the Lehman Brothers collapsed in September 2008, the market dried up as investors turned to government bonds and other less risky assets. To prevent the credit crunch the ECB decided in May 2009 to purchase covered bonds. The importance of covered bond market as a source of funding for financial institutions and their relative soundness in terms of credit risk made them the perfect target for the ECB intervention. The ECB announced on May 7, 2009 that it would purchase euro-denominated covered bonds of the amount of around €60 billion issued in the euro area. This decision was surprising for the markets which were expecting the rate cut and the lengthening of the lending program but not direct purchases of the private debt, which was perceived as a change in strategy.¹³ The objective of the Covered Bond Purchase Programme (CBPP) as stated in the decision of the ECB of July 2, 2009 (ECB/2009/16) were the following: (a) promoting the ongoing decline in money market term rates; (b) easing funding conditions for credit institutions and enterprises; (c) encouraging credit institutions to maintain and expand their lending to clients; and (d) improving market liquidity in important segments of the private debt securities market. All along the implementation of the CBPP, the ECB officials

¹³ "Trichet Drags ECB Into New Era Over Weber's Bond Objections", May 7, 2009, Bloomberg.

claimed that the covered bond purchases were not quantitative easing but a part of “enhanced credit support operations”. In other words, the ECB did not intend to create money to buy covered bonds but revive an illiquid market. The ECB intended these operations to be naturally sterilized as the euro area banks would demand less liquidity from the ECB’s refinancing operations.

In the end of June 2010 the ECB stopped the covered bond purchasing but as the sovereign crisis deepened in autumn 2011 it proceeded to further measures supporting the covered bond markets. On October 6, 2011 it announced the new covered bond purchase programme (CBPP2) and decided to allocate €40bn to this twelve-month program and to purchase euro-denominated covered bonds in both primary and secondary markets (see Figure 3.3 for the amounts purchased in CBPP 1 and 2).

3.2.3 Collateral easing

Since the creation of the euro area the ECB had a collateral framework that was much less restrictive than the Fed and the Bank of England. Therefore, the loosening of the collateral rules was not as significant as it was in the U.S in the beginning of the crisis. For instance, the commercial paper was eligible as collateral at the ECB while the Fed had to implement a specific lending facility in order to purchase it (Commercial Paper Funding Facility). However, after the Lehman Brothers collapse, the ECB significantly loosened its collateral rules (see Table 3.4). On October 15, 2008 it decided to accept as an eligible collateral debt instruments issued by credit institutions, which are traded on the accepted non-regulated markets (bank certificate of deposit among others). While widening the collateral accepted in its lending operations, the ECB sought to limit its exposure to risky assets by applying haircuts on the accepted securities. Also, since the end of 2008 it started preparing the ground to unwind emergency collateral measures and raised the requirement especially concerning the asset-backed securities (ABS). However, in Spring 2010 the sovereign debt crisis began and the ECB was obliged to further relax its collateral requirements. In particular, it took several measures to ensure that the Greek banks would still be able to use Greek government bonds as a guarantee to obtain central bank funds. As the sovereign

debt crisis spread to other euro area countries, in 2011 the ECB took the same decisions in favor of Irish and Portuguese government bonds. Moreover, in December 2011 the ECB decided to further reduce some ABS ratings thresholds and to accept loans to small and medium-sized enterprises for the first time. In February 2012, another important innovation was announced: each national central bank would accept divergent types of collateral to accommodate the peculiarities of their country banking industries.

Loosening the collateral requirements could affect the money markets via two channels. First of all, it increased the volume of collateral that could be used as a guarantee in refinancing operations and therefore lowered the liquidity constraint for the banks. It was particularly important when the sovereign debt crisis started as the banks were holding important amounts of their country debt instruments. Furthermore, accepting lower-graded assets might have contributed to lowering the interest rates on accepted instruments via portfolio rebalancing effect.

3.3 Methodology

The objective of this chapter is to assess the effectiveness of all ECB unconventional monetary policies in reducing the market borrowing costs for banks and governments between 2007 and 2012. We apply event-based regression methodology in order to measure the impact of each non-standard measure on the euro-area money market, covered bond markets and sovereign bond markets. Event-based regression allows testing the impact of an economic event on financial market data.¹⁴ In modern financial markets, as these of the euro area, the effect of the event should be reflected in asset prices over a short period of time.

We rely on dummy variables to discriminate between days when announcements were made or not. Based on the ECB press releases we create a database of monetary policy news. The announcements are classified into following categories (as described in Section 3.2):

- Exceptional liquidity provisions
 - Fixed-rate full-allotment procedure (FRFA)

¹⁴See MacKinlay (1997).

- Three-year refinancing operations (3y LTRO)
- Longer-term refinancing operations of maturity greater than 3 months
- Liquidity in foreign currencies
- Collateral easing
- Covered bond purchases (CBPP1 and CBPP2)
- Longer-term sovereign bond purchases (Securities Markets Programme, SMP)
- Short-term sovereign bond purchases (Outright Monetary Transactions, OMT)

The advantage of the event-based regression with respect to standard event study methodology is that there is no need to make an assumption as for which announcement (event) was the most important on a specific day. It seems particularly important during the crisis when there were several policy actions announced on the same day. On May 7, 2009 for instance, the ECB introduced the covered bond purchase program and one-year longer-term refinancing operations. On December 8, 2011, the three-year refinancing operations were announced along with significant collateral rules easing. Moreover, other then monetary news could also affect the market borrowing costs. When these events coincide with monetary policy announcements it is necessary to include them into regression in order to distinguish the effects. We use Factiva press database to check if there were other major events that might have influenced the variable of interest, i.e. interest rates spreads.¹⁵ The most striking example of simultaneous announcements is the weekend of 8-9 May 2010 when several monetary measures were decided and in particular the SMP was created. In parallel, the euro-area politicians founded the European Financial Stability Fund (EFSF). Even though both SMP and EFSF were intended to purchase sovereign debt it is useful to separate the effects of the two measures as they are conducted by different institutions. To assure a correct specification of our event-based regression model we include announcement concerning the EFSF and the European Stability Mechanism developments as well as the dummy for sovereign debt crisis. The crisis dummy is equal to 1 during the periods when the

¹⁵Factiva is an information and research tool owned by Dow Jones & Company. It offers online articles from both licensed and free sources (Wall Street Journal, Reuters, Financial Times among others).

concerns about solvency of the periphery euro-area were the highest.¹⁶ The ECB conventional monetary policy is also taken into account as the updates about the future ECB interest rates decisions are immediately priced into market interest rates. These surprises may be important if they are announced on the same day as unconventional monetary measures. First, we account for the unanticipated ECB interest rates decisions identified based on Reuters poll and Bloomberg surveys.¹⁷ Second, we include the surprises about the “path” of the ECB interest rates that are defined as the surprise information of the interest rates hikes (cuts) in the following month. We rely on articles in Factiva to determine the surprises in the ECB interest rates “path”.¹⁸ Given that we investigate the responses of interest rates longer than three month, both current interest rates surprise as well as the surprises about the future interest rates changes matter for this study.

We use daily data from July 2, 2007 until September 27, 2012 with the exception of Italian and Portuguese covered bond series available respectively from January 2, 2009 and October 31, 2008.

3.4 Results

3.4.1 Money market

Since August 2007 the uncertainty concerning the health of banks’ balance sheet was unusually high and financial institutions were reluctant to lend to each other. They were hoarding liquidity for their own unexpected liquidity needs but also out of concern about the counter-party financial soundness. As a result, the spreads between unsecured and secured rates increased to previously unseen levels (Figure 3.1). The spread decreased significantly in 2009 but it never attained the pre-crisis level and increased again with the onset of the euro-area

¹⁶We define the crisis dummy according to Google Trends which show how often a particular search-term (“euro-area sovereign debt crisis” in our case) is entered relative to the total search-volume across various regions of the world. The results were cross-checked with main sovereign debt crisis events reported by Reuters, The Wall Street Journal and The Daily Telegraph in their crisis timelines.

¹⁷We thank Tomasz Orpiszewski and Antoine Bouveret for their help with obtaining the data.

¹⁸For instance: 1) “No change in interest rates now, hike possible in September”, Agence Europe, August 3, 2007: “On Thursday 2 August, the European Central Bank (ECB) decided to keep the euroarea interest rates unchanged. (...) The ECB made a surprise move, however, by holding a press conference after the meeting to explain its short-term plans. (...) it organized a press conference to prepare the financial markets for an expected tightening of the monetary belt in September.” 2) “Bunds lower as markets digest ECB rate shock”, Reuters News, March 3, 2011: “Yields pushed sharply higher and the curve flattened on Thursday after the European Central Bank stunned markets by indicating it could raise interest rates as soon as next month.”

sovereign debt crisis. The interbank lending is a key element of the successful monetary transmission and the ECB was determined to support money market activity. The exceptional liquidity measures, relaxed collateral rules and covered bond purchasing programs were particularly aimed at restoring the interbank lending.

To test the impact of all announcements on the money market spreads we estimate the following regression:

$$\Delta S_t^M = \alpha + \sum_{i=1}^I \beta_i NC_{i,t} + \varphi_1 F_t + \varphi_2 C_t + \gamma x_t + \sum_{n=1}^N \psi_n \Delta S_{t-n}^M + \sum_{l=1}^7 \psi_l D_{l,t} + \epsilon_t$$

where $NC_{i,t}$ are dummies for unconventional monetary policy announcements discussed in section 3.2; F_t is a dummy for EFSF/ESM announcements; C_t is a dummy for sovereign debt crisis; x_t is a dummy for the ECB policy rate/policy path surprise; ΔS_{t-n}^M are lagged values of dependent variable included to correct for the auto-correlations of the residuals (number of lags $n = 3$); $D_{l,t}$ are dummies for the day of the week (Monday, Tuesday...) and ϵ_t is a stochastic error term.

The dependent variable ΔS_t^M is a 2-day change in 3-month money market spreads. We use four alternative measures of money market distress reflecting the difference between unsecured and secured (or riskfree) three-month lending rates: i) Euribor - OIS¹⁹, ii) Euribor - Repo²⁰, iii) Euribor - Germany Treasury bill and iv) certificate of deposit (CD) - OIS²¹. Among these measures, the Euribor-OIS is the most commonly cited barometer of the situation on the interbank market.

There is a timing issue related to the Euribor-OIS spread. Euribor rate is published at 11:00 a.m Brussels (10:00 GMT) time while the OIS rate is taken from the Datastream and the last update is from 19:15 GMT. Therefore, many announcements on a given day are not taken into account by Euribor rate. In order to ensure that the markets had the possibility to react to all announcements we consider 2-day event

¹⁹The Euro Interbank Offered Rate (Euribor) is an average interbank borrowing rate published daily at 11:00 a.m. (Brussels time) by the European Banking Federation (EBF). The overnight-indexed swap (OIS) rate represents market expectations of the monetary policy rate over the future months. There is no exchange of principal and only the net difference in interest rates is paid at maturity, so there is very little default risk in the OIS market.

²⁰Repo is the rate at which, at 11.00 a.m. Brussels time, one bank offers, in the euro-area and worldwide, funds in euro to another bank if in exchange the former receives from the latter the best collateral within the most actively traded European repo market.

²¹Certificate of deposit is a debt instrument issued by banks and other financial institutions.

window for all measures.

Another issue is related to the recent revelations about Libor and Euribor manipulation by one of the contributing banks. However, there are two particular features of Euribor rate that make it less sensitive to manipulation than Libor. First, 43 banks contribute to Euribor as opposed to 15 in the Euro Libor panel, which reduces the weight of the eventual misreporting contributor. Second, Euribor is an average lending rate while Libor is an average borrowing rate. During crisis, the contributing banks are more inclined to diminish the latter as high borrowing rates send the negative signal about their financial standing.

Table 3.5 reports the estimation results. The money market spreads react relatively little to monetary policy announcements. However, following the 3-year LTRO announcement all spreads diminish significantly. The Euribor-OIS spread is reduced by 24 basis points while Euribor-Repo and Euribor-German Treasury bill by respectively 20 and 6 basis points. The coefficient is not reported for the CD-OIS spread as there was no quotation for 3-month certificate of deposit on the day of the announcement. Similarly, the spreads go down on the days of the two 3-year LTRO operations. The effect is smaller than the announcement effect for the Euribor spreads (3-6 basis points) but reaches 13 basis points for the CD-OIS spread. Surprisingly, lengthening the LTRO to six and one year did not have the same effect which confirms that 3-year operations were indeed exceptional measure and incomparable by its scope to other liquidity facilities.²² The fact that other longer-maturity LTROs did not diminish spreads can be due to several reasons. First, by furnishing unlimited liquidity provisions to banks the ECB substituted itself for the interbank market and might have caused a “crowding out” effect as also shown in Brunetti et al. (2011). As there is unlimited liquidity available at the central bank there is no need to borrow it from the interbank market. Second, the liquidity risk was not the most important determinant of the spreads (Angelini et al. (2011)) and therefore liquidity measures were not able to affect them. In that case, only more risk-taking by the ECB (purchasing of assets, 3y LTRO for instance) would lower the spreads.

²²In order to verify the robustness of this result we included intro regression other supplementary liquidity announcement: supplementary LTROs and Special-Term LTROs. We also included different types of open market operation (regular LTROs, MROs, fine tuning) and none of these reduced the money markets spreads.

Covered bond purchases indeed diminished the spreads but the significance of the results is smaller. The effects range from 15 to 37 basis points but only the impact for the CD-OIS spread is significant at 5%.²³ On the other hand, sovereign bond purchases (SMP and OMT) did not have significant impact on money market spreads.

3.4.2 Covered bond market

Another important source of bank refinancing is covered bond markets. The ECB unconventional measures, and the covered bond purchasing programs in particular, were designed to reduce the cost of longer-term bank borrowing. In order to measure the impact of these measures we estimate the following regression:

$$\Delta S_t^C = \alpha + \sum_{i=1}^I \beta_i NC_{i,t} + \varphi_1 F_t + \varphi_2 C_t + \gamma x_t + \sum_{n=1}^N \psi_n \Delta S_{t-n}^C + \sum_{l=1}^7 \psi_l D_{l,t} + \epsilon_t$$

where $NC_{i,t}$ are dummies for unconventional monetary policy announcements; F_t is a dummy for EFSF/ESM announcements; C_t is a dummy for sovereign debt crisis; x_t is a dummy for the ECB policy rate/policy path surprise; ΔS_{t-n}^C are lagged values of dependent variable included to eliminate the auto-correlations of the residuals for all series with the exception of the UK data where the residual were not autocorrelated (number of lags $n = 1$); $D_{l,t}$ are dummies for the day of the week (Monday, Tuesday...) and ϵ_t is a stochastic error term.

ΔS_t^C is a 1-day change in covered bond spread in the euro area and in the member countries, in particular Germany, France, Italy, Ireland, Portugal and Spain.²⁴ The UK covered bond rates are also employed in order to compare a response of non euro-area rates to the ECB policies. All covered bond rates are synthetic benchmark provided by Iboxx and available from Datastream. These benchmark rates cover all bonds maturities exceeding one year and are comparable among countries. The composed-maturity bonds indexes seem appropriate as the ECB bought covered bonds of different maturities.²⁵ The spread is calculated with respect to corresponding all-maturities German sovereign

²³Result are significant at 10% for Euribor-Repo and Euribor-German bill spreads.

²⁴Datastream does not provide the Iboxx covered bond rates for Greece.

²⁵CBPP 1: 3-10 years, with strong focus on maturities up to 7 years; CBPP 2: Up to 10.5 years residual maturity, according to ECB website.

bond, also provided by Iboxx (Datastream). The UK covered bond spread takes as a reference all-maturities UK sovereign bond yield.

Table 3.6 presents the estimation results for the euro-area, France, Germany and the UK while Table 3.7 the results for Southern European countries: Ireland, Italy, Portugal and Spain. At the euro-area level, the policies that diminished the covered bond spread the most were long-term sovereign bond purchases, SMP (20 bp), followed by covered bond purchases²⁶ (6 bp), short-term sovereign bond purchases, OMT (5 bp) and 3y LTRO announcement (3 bp). The positive news concerning the EFSF/ESM also diminished spreads (4 bp) while sovereign crisis dummy increased it (1 bp).

Breaking up the results by country allows seeing the differentiated impact of the ECB measures on the spreads. The SMP had by far the strongest effect on all euro-area countries studied but the spread reduction was the most significant for Portugal (164 bp) and Ireland (49 bp) and the least for Germany and France (respectively 12 and 8 bp). The biggest impact for the periphery euro area countries suggests that the covered bonds from these countries benefited from the “spill-over effect” from the sovereign bond yields reduction (see next sub-section) which are often used as a benchmark for other longer-term rates.²⁷ More importantly however, longer-term sovereign bond purchases diminished sovereign default risk in these countries which had positively impact on business climate and the credit standing of its financial institutions who held important amount of sovereign debt. The announcement of short-term government bonds purchases (OMT) also diminished covered bond spreads in all euro-area countries studied but the magnitude of the effects was smaller ranging from 46 bp for Portugal to 3 bp for France.

As far as covered bond purchases are concerned (CBPP 1 and 2), they were significant only for Italy (16 bp), Germany (10 bp), Spain (10 bp) and France (4 bp). These results are not surprising given that according to ECBC (2010) the biggest amounts of the CBPP 1 were allocated to the central banks of Germany, France, Italy, Spain and Netherlands. Furthermore, Italy and Finland were the main beneficiaries when the ratio of purchased amounts to the size of the outstanding

²⁶We tested CBPP 1 and CBPP 2 separately and they both have similar impact on covered bond spreads.

²⁷Covered bonds are highly correlated with government bonds (correlation of 91% between July 2006 and March 2010 as reported by ECBC (2010)).

covered bonds eligible under the CBPP 1 is taken into account.

The impact of 3-year LTRO also differs for each country and was significant for Ireland (6bp) and France (4bp). The overall impact for the euro area is significant (3 bp). 3y LTRO reduced longer-term bank funding constraints and therefore diminished their credit risk pulling the yield on their debt down.

As expected, the reaction of the UK covered bonds are quite different to euro-area covered bonds. The sovereign crisis dummy enters in the UK covered bond spread with negative sign which means that the sovereign-debt crisis in euro area redirected investors to UK covered bonds (flight to quality). Furthermore, the UK covered spreads did not react to ECB measures that were significant for the euro-area spreads: sovereign and covered bond purchases, and 3y LTRO.²⁸

3.4.3 Sovereign bond market

Since the beginning of the euro-area debt crisis the spreads between the euro-area periphery sovereign yields and German sovereign yields increased dramatically. We measure the impact of the ECB unconventional measures and in particular of government bonds purchasing programs (SMP and OMT) on the euro-area long-term sovereign spreads. We compare these effects to the impact of sovereign bond purchases by the Fed and the Bank of England on the US and the UK sovereign spreads. To this end, we estimate the following equation:

$$\Delta S_t^S = \alpha + \sum_{i=1}^I \beta_i NC_{i,t} + \sum_{j=1}^2 \delta_j Q_{j,t} + \varphi_1 F_t + \varphi_2 C_t + \gamma x_t + \sum_{n=1}^N \psi_n \Delta S_{t-n}^S + \sum_{l=1}^7 \psi_l D_{l,t} + \epsilon_t$$

where $NC_{i,t}$ are dummies for unconventional monetary policy announcements; $Q_{j,t}$ are dummies for the sovereign bond purchase announcements by the Fed (δ_1) and the Bank of England (δ_2); F_t is a dummy for EFSF/ESM announcements; C_t is a dummy for sovereign debt crisis; x is a dummy for the ECB policy rate/policy path surprise;

²⁸The response of the UK spread is only indicative and is reported to show the contrast in U.K. rates responses compared to the euro area. For more formal analysis of the UK spread we would need to make sure that the important UK announcements (for example Bank of England monetary surprises) do not coincide with the ECB announcements but this analysis is beyond the scope of our study.

ΔS_{t-n}^S are lagged values of dependent variable included to eliminate the auto-correlations of the residuals for all series with the exception of the UK data where the residuals were not auto-correlated (number of lags for the euro-area series $n = 1$, U.S. series $n = 2$); $D_{l,t}$ are dummies for the day of the week (Monday, Tuesday...) and ϵ_t is a stochastic error term.

Dependent variable ΔS_t^S is a 1-day change in 10-year sovereign bond spread. The spread is calculated as a difference between the 10-year sovereign bond yield of the euro-area member country (France, Greece, Ireland, Italy, Portugal and Spain) and the 10-year German sovereign bond yield. The spreads for the Germany, the UK and the US are defined as 10-year sovereign bond yield and the 10-year interest rate swap.

Table 3.8 presents the results for the euro area, Greece, Italy, Ireland, Portugal and Spain, while the Table 3.9 the results for Germany, France, the UK and the US. The most striking result in the euro area is the impact of the ECB sovereign bond purchasing program (SMP) which reduced the spreads by 17 bp. This confirms the economic intuition that increasing the demand for these assets would reduce their risk premium as predicted by Vayanos and Vila (2009). The effect is particularly strong for the countries where the risk attained the highest levels: Greece (476 bp), Ireland (117 bp) and Portugal (205 bp). Italy and Spain acknowledge the reduction of respectively 35 and 44 basis points while French and German spreads do not react. The SMP program was announced without any precision about the amounts nor about the regularity of the purchases. The market participant discovered every Monday the quantities of bonds that the ECB purchased. The analysts say that the ECB purchased mostly Greek, Irish and Portuguese bonds which is reflected in regression results.²⁹

The SMP was never officially stopped but there was however one more important date, August 7, 2011, as the crisis was about to spread to Italy and Spain. On that day the ECB confirmed its willingness to purchase actively the euro-area sovereign bonds. This announcement was preceded by a positive appreciation of the Italian and Spanish austerity program execution and was unambiguously understood as a promise to buy Italian and Spanish government bonds. We take this

²⁹Reuters, August 1, 2011, "ECB keeps bond-buying programme dormant", article available at <http://www.reuters.com/article/2011/08/01/ecb-bonds-idUSEAP50O13520110801>

announcement into account and report the results in Table 3.10. The overall SMP effect for the euro-area increased: 23 bp reduction in the benchmark euro spread but the effect is significant only for Italy and Spain (respectively 65 and 84 basis points).

The second sovereign bond purchasing program, OMT, had similar but smaller impact on benchmark euro area sovereign spreads (13 bp). The program was announced in a view of helping Spain and the Spanish spreads reacted the most to that measure (56 bp). The impact for Italian and Portuguese spreads was also significant at 5% (respectively 28 and 43 bp) but for Irish spreads only at 10% (27 bp) and not significant for Greek spreads. Again, the French and German spreads did not react to the announcement. The conditionality attached to the program might have contributed to smaller response of Greek and Irish bonds. Indeed, when we take into account the speech of Mario Draghi on July 26, 2012, in which he promised to “do whatever it takes to save euro”, the response of Greek rates was significant and high: 38 bp (Table 3.11). 26-July announcement triggered expectations of unlimited euro-area bonds buying and targeting a specific level of spreads that were further dismissed in the final version of the program. The smaller OMT impact could be also linked to the maturity of purchased bonds, smaller than three years, whereas SMP concerned longer-term bonds. Finally, the smaller impact of subsequent asset purchasing programs seem to be a general response of financial markets, also valid for asset purchases in the U.S. and in the U.K where the first programs had far greater impact on sovereign bonds and on corporate bond yields than the later programs Meaning and Zhu (2011).

As a comparison, we show that the U.S. and U.K. sovereign spreads also fell following the sovereign bond purchases announced by the Fed and the Bank of England but the magnitude of the effect was much smaller: respectively 5 and 9 basis points. The strong impact in the euro area suggests that the central bank intervention in sovereign market is particularly effective when the sovereign risk is important. The fall of the sovereign bond markets following the EFSF/ESM-linked announcements (13 bp) confirms that measures that aimed at default risk reduction were effective in reducing government borrowing costs in the euro area.

Covered bond purchase programs were another measure that reduced the sovereign spreads (7bp). The puzzling result however, is the reaction of the sovereign spreads following the important 3y LTRO announcement. The spreads rise especially in the Southern European countries. The reaction of sovereign spreads is particular as the impact of the 3y LTRO on interbank market and covered bonds was very significant and in line with expectations. This result shows that 3y LTRO improved significantly market borrowing costs for banks but not for the governments. Given that 3y loans were granted to banks this comes as no surprise. However, the 3y LTRO announcement significantly *increased* the government borrowing costs. This reaction suggests that market participants were disappointed with the ECB not reactivating its bond purchasing program and did not believe the 3y LTRO would be enough to solve the euro-area debt crisis. The press on that day confirms this disappointment.³⁰ The reaction of the sovereign spreads to 3y LTRO seems to confirm that sovereign bond markets in euro area were mostly driven by the market perception of the sovereign default risk and hence the measures that diminished that risk were the most successful in reducing the spreads.

3.5 Conclusion

The empirical evidence from the event-based regressions shows that only the most spectacular ECB unconventional monetary policies, namely sovereign bond purchases (SMP and OMT), covered bond purchases (CBPP 1 and 2) and 3-year refinancing operations (3y LTRO), diminished significantly borrowing costs for banks and government. Money market spreads were most relieved after the 3-year loans were distributed to banks (3y LTRO) and after the ECB started buying longer-term bank debt (CBPP 1 and 2) but remained unaffected by smaller liquidity measures which suggests that credit risk was the banks' principal concern.

The covered bond markets reacted the most to long-term sovereign bond purchasing program (SMP) but also to short-term sovereign bond purchasing program (OMT), covered bond purchases (CBPP 1 and 2) and the 3-year LTRO. Covered bonds, as a source of banks

³⁰1) "US Stocks Fall As ECB Disappoints On Bond Buying", December 8, 2011, Wall Street Journal; 2) "ECB dampens bond-buying hopes", December 8, 2011, Reuters.

long-term refinancing, were reactive to measures addressed to banks (CBPP, 3y LTRO). However, the strong reaction to sovereign bond purchases suggests that this measure had an impact on broader class of long-term assets as it diminished the risk of sovereign default.

Finally, both OMT and SMP had important impact on the cost of government borrowing in countries directly threatened by losing access to financial markets: the effects range from 35 basis points (Italy) to 476 basis points (Greece). As a comparison, we show that the U.S. and U.K. sovereign spreads also fell following the sovereign bond purchases announced by the Fed and the Bank of England but the magnitude of the effect was much smaller: respectively 5 and 9 basis points. The strong impact in the euro area suggests that the central bank intervention in sovereign market is particularly effective when the sovereign risk is important.

3.6 Annexes

A1. Figures

Figure 3.1: Money market spread and ECB LTROs

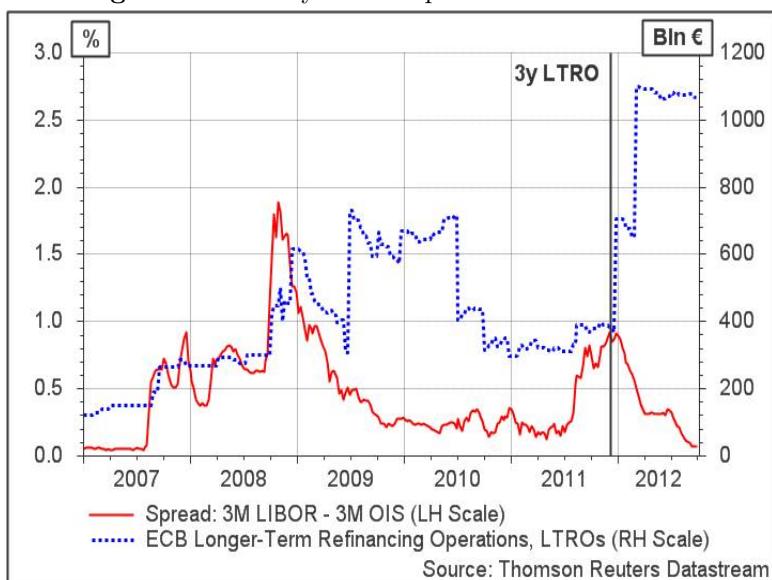


Figure 3.2: Sovereign Spreads and ECB Sovereign Bond Purchases

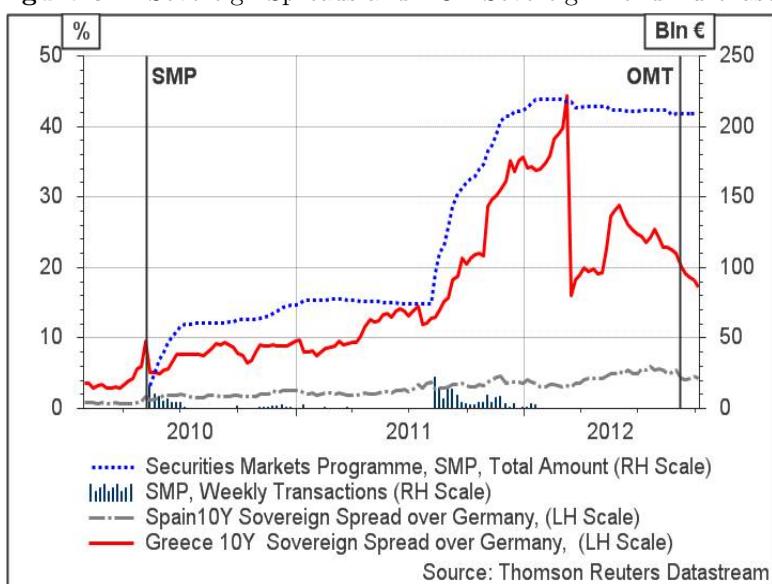
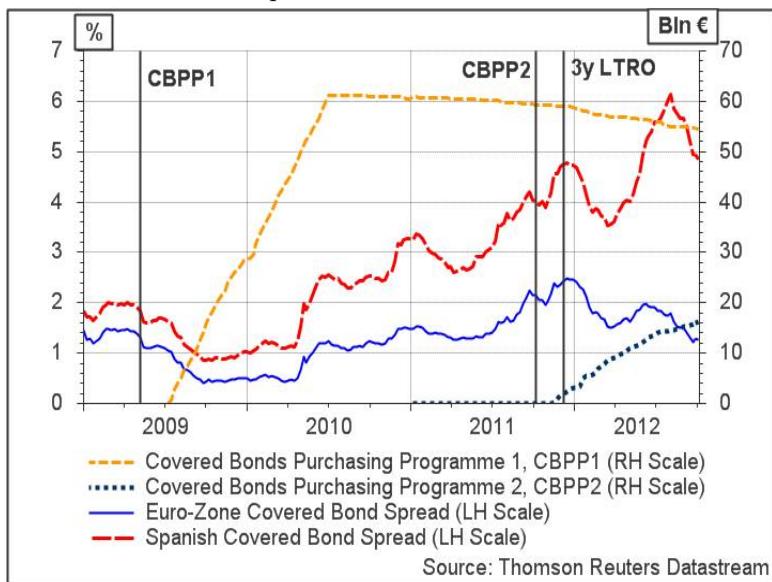


Figure 3.3: Covered Bond Spreads and ECB Covered Bond Purchases 1 and 2



A2. Tables

Table 3.1: Fixed-Rate Full-Allotment (FRFA)

Date	Description of the ECB announcement
08/10/2008	FRFA procedure in the main refinancing operations (MROs) (announced late in the evening and taken into account by markets on 09/10/2008).
13/10/2008	Liquidity in U.S. dollars (currency swaps with the Fed) provided at FRFA procedure.
15/10/2008	FRFA procedure in all longer-term refinancing operations (LTROs).
10/05/2010	Reactivation of FRFA procedure in regular longer-term refinancing operations (LTROs) (the ECB decided to return to variable-rate tender procedures in the regular LTROs on 04/03/2012).

Table 3.2: Longer-term refinancing operations of maturity above 3 months

Date	Description of the ECB announcement
28/03/2008	2 supplementary 6-month LTROs (€50 bn)
04/09/2008	Supplementary 6-month LTRO (€25 bn)
07/10/2008	Increase in allotment amount of 6-month LTRO (from €25 to €50bn)
15/10/2008	5 supplementary 6-month LTROs (FRFA procedure)
05/03/2009	ECB will continue with the current frequency and maturity profile of supplementary LTROs for as long as needed, and in any case beyond the end of 2009.
07/05/2009	3 supplementary 1-year LTROs (FRFA)
10/05/2010	Supplementary 6-month LTRO (FRFA)
04/08/2011	Supplementary 6-month LTRO (FRFA)
06/10/2011	Supplementary 12-month and 13-month LTRO (FRFA)

Table 3.3: Foreign currency arrangements

Date	Currency	Description of the ECB announcement
12/12/2007	USD	Swaps with the Federal Reserve. US dollar liquidity-providing operations up to \$20 billion, for a maturity of: 28 and 35 days.
11/03/2008	USD	Swaps with the Federal Reserve increased by \$10 billion (up to \$30 billion). The ECB commits to provide the USD liquidity for as long as needed.
02/05/2008	USD	Swaps with the Federal Reserve increased by \$20 billion (up to \$50 billion) and extended to Jan 30, 2009.
30/07/2008	USD	Swaps with the Federal Reserve increased by \$5 billion (up to \$55 billion). 84-day auction introduced.
18/09/2008	USD	Swaps with Fed expanded to \$110 billion.
26/09/2008	USD	Swaps with Fed expanded to \$120 billion. 1-week auction introduced.
29/09/2008	USD	Swaps with Fed expanded to \$240 billion and extended through April 30, 2009.
13/10/2008	USD	US dollar liquidity-providing at fixed-rate full-allotment basis.
15/10/2008	USD CHF	USD liquidity also through EUR/USD foreign exchange swaps (in parallel with existing tenders against ECB-eligible collateral). Swaps lines with SNB to provide Swiss Francs in euro area.
03/02/2009	USD	Swap lines between the Federal Reserve and ECB extended to October 30, 2009.
25/06/2009	USD CHF	Swap lines between the Fed and ECB extended until February 1, 2010. 1-week Swiss franc liquidity-providing swap operations extended until at least 31 October 2009.
10/05/2010	USD	Reactivation of the swap lines with the Federal Reserve (USD liquidity-providing operations at terms of 7 and 84 days as fixed rate tenders with full allotment).
17/12/2010	GBP	ECB and BOE announce liquidity swap facility: GBP liquidity-providing operations up to £10 billion.
21/12/2010	USD	Swap line between the Federal Reserve and ECB extended to August 1, 2011.
29/06/2011	USD	Swap line between the Federal Reserve and ECB extended to August 1, 2012.
25/08/2011	GBP	Swap line between the BOE and ECB extended to September 28, 2012.
15/09/2011	USD	Fed and ECB decide to conduct 3 USD liquidity-providing operations with a maturity of approx. 3 months covering the end of the year.
30/11/2011	JPY GBP CHF CAD USD	Establishment of a temporary network of reciprocal swap lines with other central banks to provide liquidity operations, should they be needed, in Japanese yen, sterling, Swiss francs and Canadian dollars. ECB reduced the charge for the USD liquidity (-50bp) and extended the size and timing of the swap lines.

Table 3.4: Collateral

Date	Description of the ECB announcement
15/10/2008	ECB expands accepted collateral (until the end of 2009): debt in non-euro currencies; euro-denominated syndicated credit governed by UK law; some debt instruments of credit instruments traded on non-regulated markets (for ex. CDs); some subordinated debt instruments.
07/05/2009	Prolongation until the end of 2010 of the temporary expansion of the list of eligible assets, announced on 15 October 2008.
22/03/2010	Jean Claude Trichet signals the possibility to ease collateral rules if Greek bonds not eligible.
08/04/2010	The ECB reveals its revamped collateral scheme that allows banks to pledge as collateral lower-rated investment-grade debt (also sovereign Greek bonds); certain exceptional collateral no longer accepted from Jan. 1, 2011.
03/05/2010	ECB announces the suspension of the rating threshold for debt instruments of the Greek government
31/03/2011	ECB announces the suspension of the rating threshold for debt instruments of the Irish government
07/07/2011	ECB announces change in eligibility of debt instruments issued or guaranteed by the Portuguese government
21/09/2011	ECB increases the pool of assets it accepts as collateral against loans from Jan1, 2012, accept for ex instruments issued by credit institutions and traded on non-regulated markets but tighten its rules on banks using their own unsecured bonds as collateral
08/12/2011	ECB reduces the rating threshold for some ABS and allowing national central banks to accept credit claims (for ex. bank loans) as collateral.
09/02/2012	ECB relaxes collateral rules; Collateral regulations for ECB loans vary by country (following 8/12/11 that allows additional performing credit claims as collateral)
08/03/2012	ECB reactivates eligibility of Greek bonds as collateral
22/06/2012	ECB reduces the rating threshold and amends the eligibility requirements for certain ABSs
06/09/2012	ECB announces the suspension of the rating threshold for debt instruments of countries that are eligible for OMT or are under an EU-IMF program and comply with the attached conditionality as assessed by the ECB

Table 3.5: Money Market Spreads

MONEY MARKET SPREADS = 3M unsecured - 3M "safe" rate				
3-month	Euribor- -OIS	Euribor- Repo	Euribor- German	CD- OIS
Sovereign crisis dummy	0.00 [0.39]	0.00 [0.30]	0.00 [0.55]	0.00 [0.32]
EFSF	0.02 [0.27]	0.02* [0.09]	0.02 [0.64]	-0.01 [0.86]
ECB policy rates surprises	0.13* [0.08]	0.04 [0.80]	-0.08 [0.38]	0.13 [0.34]
Covered Bonds P.P. 1 and 2	-0.21 [0.11]	-0.37* [0.10]	-0.17* [0.07]	-0.15** [0.03]
Securities Markets Prog.(SMP)	0.19 [0.45]	-0.02 [0.93]	-0.36* [0.05]	0.01 [0.96]
Outright Monetary Trans.(OMT)	-0.04 [0.15]	-0.06* [0.08]	-0.01 [0.63]	
Collateral easing	0.02 [0.42]	0.04 [0.24]	0.00 [0.97]	0.03 [0.35]
3Y LTRO annoucement	-0.24*** [0.00]	-0.20*** [0.00]	-0.06** [0.03]	
3Y LTRO operations	-0.06** [0.02]	-0.06** [0.05]	-0.03*** [0.01]	-0.13*** [0.00]
Fixed-rate full-allotment	-0.38 [0.19]	-0.19 [0.51]	0.15 [0.42]	-0.10 [0.54]
Longer maturity LTRO	0.13 [0.31]	0.21 [0.12]	0.12 [0.22]	0.10 [0.12]
Swaps agreements	0.01 [0.79]	0.01 [0.89]	0.04 [0.32]	0.04 [0.28]
Observations	1,365	1,365	1,278	1,187
R-squared	0.49	0.61	0.33	0.23

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;
Lags of dependent variables, constant and day dummies not reported.

Table 3.6: Covered bonds: Euro area, Germany, France, UK

COVERED BOND SPREAD = Covered bond rate - German (UK) sovereign bond rate	Euro area	France	Germany	(UK)
Sovereign crisis dummy	0.01*** [0.00]	0.01*** [0.00]	0.00** [0.02]	-0.01*** [0.01]
EFSF	-0.04*** [0.00]	-0.02*** [0.00]	-0.03*** [0.00]	-0.00 [0.99]
ECB policy rates surprises	-0.02 [0.48]	-0.02 [0.40]	0.01 [0.58]	-0.02 [0.25]
Covered Bonds P.P. 1 and 2	-0.06*** [0.00]	-0.04*** [0.00]	-0.08*** [0.01]	0.04 [0.30]
Securities Markets Prog.(SMP)	-0.20*** [0.00]	-0.08*** [0.00]	-0.12*** [0.00]	0.08 [0.22]
Outright Monetary Trans.(OMT)	-0.05*** [0.00]	-0.03*** [0.00]	-0.04*** [0.00]	0.09* [0.09]
Collateral easing	-0.01 [0.18]	-0.01 [0.36]	-0.01 [0.22]	0.00 [0.92]
3Y LTRO announcement	-0.03*** [0.00]	-0.04*** [0.00]	-0.01* [0.07]	0.10* [0.06]
3Y LTRO operations	-0.01 [0.34]	-0.01 [0.20]	-0.01 [0.76]	0.03 [0.33]
Fixed-rate full-allotment	-0.04 [0.13]	-0.04 [0.23]	-0.03 [0.41]	-0.12*** [0.00]
Longer maturity LTRO	0.02 [0.14]	0.01 [0.41]	0.04 [0.15]	0.06*** [0.01]
Swaps agreements	-0.00 [0.83]	0.00 [0.60]	-0.01 [0.12]	-0.02 [0.15]
Observations	1,368	1,368	1,368	1,369
R-squared	0.13	0.08	0.07	0.04

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;
Lags of dependent variables, constant and day dummies not reported.

Table 3.7: Covered bonds: Ireland, Italy, Portugal, Spain

COVERED BOND SPREAD = Covered bond rate - German sovereign bond rate					
	Euro area	Ireland	Italy	Portugal	Spain
Sovereign crisis dummy	0.01*** [0.00]	0.01*** [0.00]	0.02*** [0.00]	0.04*** [0.00]	0.02*** [0.00]
EFSF	-0.04*** [0.00]	-0.06*** [0.00]	-0.06*** [0.00]	-0.12* [0.07]	-0.08*** [0.00]
ECB policy rates surprises	-0.02 [0.48]	-0.01 [0.57]	0.02 [0.19]	-0.01 [0.91]	-0.04 [0.18]
Covered Bonds P.P. 1 and 2	-0.06*** [0.00]	-0.02 [0.82]	-0.16** [0.02]	-0.08 [0.48]	-0.07*** [0.00]
Securities Markets Prog.(SMP)	-0.20*** [0.00]	-0.49*** [0.00]	-0.38*** [0.00]	-1.64*** [0.00]	-0.35*** [0.00]
Outright Monetary Trans.(OMT)	-0.05*** [0.00]	-0.12*** [0.00]	-0.08*** [0.00]	-0.46*** [0.00]	-0.10*** [0.00]
Collateral easing	-0.01 [0.18]	0.02 [0.50]	-0.03 [0.10]	-0.04 [0.35]	-0.02* [0.06]
3Y LTRO announcement	-0.03*** [0.00]	-0.06** [0.02]	-0.01 [0.60]	0.07 [0.58]	-0.01 [0.20]
3Y LTRO operations	-0.01 [0.34]	-0.01 [0.69]	-0.04 [0.16]	0.00 [0.98]	-0.01 [0.31]
Fixed-rate full-allotment	-0.04 [0.13]	-0.07 [0.15]			-0.06** [0.05]
Longer maturity LTRO	0.02 [0.14]	0.05 [0.23]	0.08 [0.26]	0.01 [0.92]	0.01 [0.22]
Swaps agreements	-0.00 [0.83]	0.01 [0.26]	-0.01 [0.45]	-0.01 [0.88]	-0.00 [0.81]
Observations	1,368	1,368	973	1,018	1,368
R-squared	0.13	0.13	0.17	0.27	0.20

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;
Lags of dependent variables, constant and day dummies not reported.

Table 3.8: Sovereign bond spreads: Greece, Ireland, Italy and Spain

	SOVEREIGN SPREAD = 10Y Country government bond - 10Y German gov. bond	Euro area	Greece	Ireland	Italy	Portugal	Spain
Sovereign crisis dummy	0.01** [0.04]	0.13*** [0.00]	0.02** [0.01]	0.02** [0.05]	0.02 [0.20]	0.02 [0.02]	0.02** [0.02]
ECB policy rates surprises	-0.01 [0.15]	-0.36 [0.30]	-0.02 [0.74]	-0.03 [0.19]	-0.02 [0.83]	-0.02 [0.20]	-0.06 [0.20]
EFSF	-0.13*** [0.00]	-0.24* [0.09]	-0.52*** [0.00]	-0.28** [0.01]	-0.46*** [0.00]	-0.43*** [0.00]	-0.43*** [0.00]
Covered Bonds P.P. 1 and 2	-0.07*** [0.01]	-0.36** [0.03]	-0.07 [0.59]	-0.21*** [0.00]	-0.07 [0.72]	-0.07 [0.27]	-0.11 [0.27]
SMP	-0.17*** [0.00]	-4.76*** [0.00]	-1.17*** [0.00]	-0.35*** [0.00]	-2.05*** [0.00]	-0.44*** [0.00]	-0.44*** [0.00]
OMT	-0.13*** [0.00]	-0.17 [0.40]	-0.27* [0.07]	-0.28*** [0.00]	-0.43** [0.05]	-0.43** [0.00]	-0.56*** [0.00]
Collateral easing	-0.02* [0.08]	0.22 [0.24]	0.03 [0.56]	-0.03 [0.23]	-0.11* [0.10]	-0.11* [0.29]	-0.04 [0.29]
3Y LTRO announcement	0.20*** [0.00]	1.00*** [0.00]	0.02 [0.87]	0.51*** [0.00]	0.19 [0.38]	0.19 [0.00]	0.37*** [0.00]
3Y LTRO operations	-0.00 [0.95]	-0.03 [0.84]	0.02 [0.82]	-0.01 [0.94]	0.38** [0.01]	0.38** [0.52]	0.05 [0.52]
Fixed-rate full-allotment	-0.01 [0.16]	-0.02 [0.91]	-0.00 [0.96]	-0.04 [0.10]	-0.01 [0.93]	-0.01 [0.78]	-0.02 [0.78]
Longer maturity LTRO	0.01 [0.30]	0.05 [0.51]	-0.07 [0.28]	0.05 [0.23]	-0.01 [0.95]	-0.01 [0.95]	0.00 [0.95]
Swaps agreements	-0.01 [0.52]	-0.11 [0.42]	0.02 [0.60]	-0.01 [0.70]	-0.04 [0.43]	-0.04 [0.74]	-0.01 [0.74]
Treasuries purchases (US)	0.01 [0.34]	-0.02 [0.71]	0.03 [0.56]	0.01 [0.67]	-0.00 [0.95]	0.00 [0.44]	0.03 [0.44]
Gilt purchases (UK)	0.01 [0.49]	0.03 [0.42]	0.04 [0.60]	0.02 [0.57]	0.05 [0.66]	0.05 [0.97]	-0.00 [0.97]
Observations	1,368	1,368	1,368	1,368	1,368	1,368	1,368
R-squared	0.13	0.04	0.19	0.10	0.19	0.19	0.17

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;
 Lags of dependent variables, constant and day dummies not reported.

Table 3.9: Sovereign bond spreads: Germany, France, the UK and the US

	SOVEREIGN SPREAD = 10Y Government bond - 10Y Riskfree rate	Germany	France	UK	US
	Euro area				
Sovereign crisis dummy	0.01** [0.04]	-0.00 [0.51]	0.00 [0.13]	-0.00 [0.34]	-0.00 [0.33]
ECB policy rates surprises	-0.01 [0.15]	0.01 [0.26]	-0.01 [0.60]	0.04 [0.39]	-0.01 [0.19]
EFSF	-0.13*** [0.00]	0.02 [0.11]	-0.07*** [0.00]	0.00 [0.61]	-0.00 [0.93]
Covered Bonds P.P. 1 and 2	-0.07*** [0.01]	-0.00 [0.93]	-0.02 [0.54]	0.06 [0.13]	0.02 [0.45]
SMP	-0.17*** [0.00]	-0.01 [0.78]	-0.04 [0.39]	-0.01 [0.69]	0.04 [0.28]
OMT	-0.13*** [0.00]	0.01 [0.72]	-0.05 [0.17]	-0.00 [0.89]	-0.00 [0.93]
Collateral easing	-0.02* [0.08]	-0.01 [0.25]	-0.02 [0.14]	-0.01** [0.04]	-0.01 [0.50]
3Y LTRO announcement	0.20*** [0.00]	0.07*** [0.01]	0.20*** [0.00]	-0.00 [0.96]	0.01 [0.80]
3Y LTRO operations	-0.00 [0.95]	0.00 [0.95]	-0.03 [0.24]	0.01* [0.05]	0.01 [0.76]
Fixed-rate full-allotment	-0.01 [0.16]	0.02 [0.27]	-0.01 [0.70]	0.03 [0.43]	-0.02 [0.15]
Longer maturity LTRO	0.01 [0.30]	0.02 [0.11]	0.01 [0.62]	-0.02 [0.20]	0.00 [0.72]
Swaps agreements	-0.01 [0.52]	0.00 [0.64]	-0.01 [0.42]	0.01 [0.14]	-0.00 [0.91]
Treasuries purchases (US)	0.01 [0.34]	0.00 [0.67]	0.01 [0.42]	-0.00 [0.84]	-0.05*** [0.00]
Gilt purchases (UK)	0.01 [0.49]	0.00 [0.76]	0.01 [0.49]	-0.09** [0.01]	-0.02 [0.16]
Observations	1,368	1,368	1,368	1,369	1,367
R-squared	0.13	0.08	0.06	0.06	0.25

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;

Lags of dependent variables, constant and day dummies not reported.

Table 3.10: Sovereign bond spreads: Greece, Ireland, Italy and Spain (SMP 2nd announcement)

	Euro area	Greece	Ireland	Italy	Portugal	Spain
Sovereign crisis dummy	0.01** [0.05]	0.12*** [0.00]	0.02* [0.09]	0.02** [0.05]	0.01 [0.40]	0.02** [0.01]
ECB policy rates surprises	-0.01 [0.15]	-0.36 [0.30]	-0.02 [0.62]	-0.03 [0.19]	-0.02 [0.66]	-0.06 [0.19]
EFSF	-0.12*** [0.00]	-0.83* [0.07]	-0.68*** [0.01]	-0.23** [0.04]	-0.69*** [0.00]	-0.35*** [0.00]
Covered Bonds P.P. 1 and 2	-0.07*** [0.01]	-0.22 [0.33]	-0.04 [0.75]	-0.22*** [0.00]	-0.02 [0.84]	-0.13 [0.19]
SMP	-0.23*** [0.00]	-1.65 [0.21]	-0.31 [0.41]	-0.65*** [0.00]	-0.77 [0.15]	-0.84*** [0.00]
OMT	-0.13*** [0.00]	-0.25 [0.22]	-0.29*** [0.00]	-0.27*** [0.00]	-0.46*** [0.00]	-0.55*** [0.00]
Collateral easing	-0.02* [0.06]	0.29 [0.12]	0.05 [0.35]	-0.04 [0.15]	-0.08 [0.37]	-0.05 [0.17]
3Y LTRO annoucement	0.20*** [0.00]	0.93*** [0.00]	0.00 [0.95]	0.52*** [0.00]	0.16* [0.08]	0.38*** [0.00]
3Y LTRO operations	-0.00 [0.95]	-0.03 [0.84]	0.02 [0.85]	-0.01 [0.93]	0.38 [0.12]	0.05 [0.51]
Fixed-rate full-allotment	-0.00 [0.78]	-0.53 [0.22]	-0.15 [0.22]	0.01 [0.87]	-0.22 [0.18]	0.05 [0.48]
Longer maturity LTRO	0.02 [0.16]	-0.18 [0.34]	-0.13* [0.08]	0.07* [0.10]	-0.10 [0.18]	0.03 [0.49]
Swaps agreements	-0.01 [0.55]	-0.15 [0.30]	0.01 [0.82]	-0.00 [0.82]	-0.06 [0.23]	-0.01 [0.84]
Treasuries purchases (US)	0.01 [0.34]	-0.02 [0.66]	0.03 [0.59]	0.01 [0.68]	-0.01 [0.88]	0.03 [0.42]
Gilt purchases (UK)	0.01 [0.55]	0.08 [0.21]	0.05 [0.18]	0.02 [0.68]	0.07 [0.20]	-0.01 [0.87]
Observations	1,368	1,368	1,368	1,368	1,368	1,368
R-squared	0.15	0.03	0.17	0.14	0.17	0.22

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;
Lags of dependent variables, constant and day dummies not reported.

Table 3.11: Sovereign bond spreads: Greece, Ireland, Italy and Spain (OMT 2nd announcement)

	Euro area	Greece	Ireland	Italy	Portugal	Spain
Sovereign crisis dummy	0.01* [0.05]	0.13*** [0.00]	0.02** [0.01]	0.01* [0.06]	0.02 [0.20]	0.02** [0.02]
ECB policy rates surprises	-0.01 [0.15]	-0.36 [0.30]	-0.02 [0.74]	-0.03 [0.18]	-0.02 [0.83]	-0.06 [0.20]
EFSF	-0.13*** [0.00]	-0.24* [0.09]	-0.52*** [0.00]	-0.28** [0.01]	-0.46*** [0.00]	-0.42*** [0.00]
Covered Bonds P.P. 1 and 2	-0.07*** [0.00]	-0.37** [0.03]	-0.07 [0.61]	-0.21*** [0.00]	-0.07 [0.73]	-0.11 [0.27]
SMP	-0.16*** [0.00]	-4.75*** [0.00]	-1.17*** [0.00]	-0.34*** [0.00]	-2.06*** [0.00]	-0.44*** [0.00]
OMT	-0.17*** [0.00]	-0.38** [0.02]	-0.18* [0.08]	-0.39*** [0.00]	-0.37** [0.02]	-0.57*** [0.00]
Collateral easing	-0.01 [0.16]	0.23 [0.18]	0.02 [0.68]	-0.02 [0.42]	-0.12* [0.07]	-0.04 [0.27]
3Y LTRO annoucement	0.20*** [0.00]	0.98*** [0.00]	0.03 [0.83]	0.50*** [0.00]	0.20 [0.36]	0.37*** [0.00]
3Y LTRO operations	-0.00 [0.95]	-0.03 [0.85]	0.02 [0.82]	-0.01 [0.93]	0.38** [0.01]	0.05 [0.52]
Fixed-rate full-allotment	-0.01 [0.12]	-0.02 [0.88]	-0.00 [0.98]	-0.04* [0.08]	-0.01 [0.94]	-0.02 [0.78]
Longer maturity LTRO	0.01 [0.33]	0.04 [0.54]	-0.07 [0.29]	0.04 [0.25]	-0.00 [0.96]	0.00 [0.97]
Swaps agreements	-0.01 [0.50]	-0.12 [0.41]	0.02 [0.60]	-0.01 [0.67]	-0.04 [0.43]	-0.01 [0.72]
Treasuries purchases (US)	0.01 [0.34]	-0.02 [0.71]	0.03 [0.56]	0.01 [0.67]	-0.00 [0.95]	0.03 [0.43]
Gilt purchases (UK)	0.01 [0.52]	0.03 [0.43]	0.04 [0.61]	0.02 [0.60]	0.05 [0.67]	-0.00 [0.95]
Observations	1,368	1,368	1,368	1,368	1,368	1,368
R-squared	0.14	0.04	0.19	0.12	0.19	0.19

*** p<0.01, ** p<0.05, * p<0.1 Robust pval in brackets; Long-run coefficients;
Lags of dependent variables, constant and day dummies not reported.

4 Disaster Risk in a New Keynesian Model¹

4.1 Introduction

In this chapter we build a model that is particularly suitable for analyzing unconventional monetary policies and in particular risky asset purchases. The sudden increase in risk premia driven in by investors' perception of risk contributed to decrease in asset prices and contraction of lending and finally led to recession. The central banks reacted to these developments by taking the risk on their balance sheet.

We incorporate a small and time-varying "disaster risk" à la Gourio (2012) in a New Keynesian model. A small change in the probability of disaster may affect macroeconomic quantities and asset prices. In particular, a higher disaster probability is sufficient to generate a recession without effective occurrence of the disaster. By accounting for monopolistic competition, price stickiness, and a Taylor-type rule, this chapter provides a baseline framework of the dynamic interactions between the macroeconomic effects of rare events and nominal rigidity, particularly suitable for further analysis of monetary policy.

A recent but growing literature studies how the risk of rare events — sometimes called economic "disasters" — affects the dynamic interactions between macroeconomic quantities and asset prices — risk premia in particular. However, disaster risk is still rarely accounted for in general equilibrium models, especially in the models used to conduct monetary policy where variations in the expected returns are generally entirely driven by variations in the risk-free interest rate. Yet understanding the efficiency and the desirability of monetary policy facing — realized or potential — rare events is of main interest. In order to design an appropriate intervention, studying the effects of a time-varying disaster risk in this class of models is a prerequisite.

¹This chapter was co-authored with Marlène Isoré. We thank Pierpaolo Benigno, Julio Carrillo, Benjamin Carton, Richard Clarida, Marco Del Negro, François Gourio, Salvatore Nisticò, Henri Sterdyniak, and Philippe Weil for many discussions from the early stages of this work. All remaining errors are ours.

Early papers on disaster risk were restricted to endowment economies (Rietz, 1988, Barro, 2006, Gabaix (2012)) such that policy implications could have hardly been derived. Gourio (2012) has gone a step further by introducing a small and stochastically time-varying risk premium into a real business cycle model. His model has thus provided a tractable way to analyze the feedback effects between changes in aggregate risk and the macroeconomic variables, as well as to reproduce some important empirical facts in terms of asset pricing including the countercyclicality of the risk premia. In particular, an increase in the probability of disaster leads investment and output to fall as capital becomes riskier. Meanwhile precautionary savings lower the yield on risk-free assets, such that the spread rises in distressed times.

This paper builds on Gourio's approach and introduces a time-varying risk of disaster in an otherwise standard New Keynesian DSGE model, providing a baseline framework that will allow to evaluate the role of monetary policy facing changes in the probability of rare events. The occurrence of a disaster is associated with the destruction of a share of capital, but the appealing feature of the model is that business cycles are significantly affected by the disaster risk even when disasters do not effectively arrive. We especially focus on the responses of macroeconomic quantities to a sudden small rise in the probability of disaster, and get some interesting preliminary results.

First, we are able to relax one essential assumption in Gourio's work which consists in imposing a reduction in total factor productivity by exactly the same amount than the capital stock to replicate the data. We show that the equally important output fall may occur when investment adjustment costs and monopolistic competition in intermediate goods are introduced. The response of output is much more important under time-dependent price stickiness. However, firms may be more inclined to adjust their prices when the aggregate risk rises (Caplin and Leahy, 1991), so we also allow for some state-dependent price adjustment.

Second, we find that consumption falls on impact in case of a rise in disaster risk while Gourio found the opposite response with a more stylized model. Similarly, we get a drop in wages which is not observed in the pure flexible-price but otherwise similar version of the model under both time-dependent and state-dependent price sticki-

ness. This response of wages seems more reminiscent of distressed economic times. Finally, we compare the responses of the model with and without the presence of a disaster risk to standard monetary, fiscal, and productivity shocks.

So far our model is solved under certainty-equivalence since at this stage we only study the responses of macroeconomic quantities to a (small) change in the probability of disaster instead of the responses to a (large) disaster shock. Indeed, there is a consensus that higher order approximation terms are irrelevant for macroeconomic quantities even when time-varying risk is introduced². Asset pricing on the other hand are affected by a time-varying disaster risk and require the combination of nonlinear methods and aggregate uncertainty.³ This version of the model does not study the feedback effects between macroeconomic quantities and the impact of disaster risk on asset pricing yet. However, the set-up is such that we will be able to do so in the next step by incorporating a stochastic discount factor from which the yield curve and the term premium will be derived.

The remainder of the paper is as follows. Section 4.2 develops the model, Section 4.3 discusses how the steady state is affected by the presence of a disaster risk and presents the calibration, Section 4.4 describes the response functions to a shock to the probability of disaster as well as to standard shocks. Section 4.5 gives our further research agenda, and Section 4.6 concludes.

4.2 Model

4.2.1 Households

Households consume goods, supply labor, and save through risk-free bonds and capital accumulation so as to maximize the expected discounted sum of utility flows given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{(C_t - hC_{t-1})^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\phi}}{1+\phi} \right) \quad (4.1)$$

where β is the subjective discount factor, E_0 the expectation operator,

²We solved the model using first and second order approximations and obtained almost identical results

³See Bloom (2009) for a model with uncertainty shocks for instance.

C and L consumption and labor flows respectively, h a habit formation parameter, γ the coefficient of relative risk aversion or the inverse of the intertemporal elasticity of substitution, and ϕ the inverse of the elasticity of work effort with respect to the real wage. Households own the capital stock K_t and lease a fraction u_t of it to the firms. Thus their budget constraint is

$$C_t + I_t + \frac{B_{t+1}}{p_t} \leq W_t L_t + (1 + i_{t-1}) \frac{B_t}{p_t} + R_t^k u_t K_t + \Pi_t - T_t \quad (4.2)$$

where I_t is investment, B_t are one-period bonds, w_t is the real wage, Π_t are profits from firms, and R_t^k is the real rental rate of capital, at time t .

Capital is considered as a risky asset here in the sense that it may be hit by a “disaster”. In (Barro, 2006) and (Gourio, 2012)’s spirit, a disaster occurrence may be either a war which physically destroys a part of the capital stock, the expropriation of capital holders, a technological revolution that make it worthless, or the loss of intangible capital due to a prolonged recession. We assume that the disaster destroys a share b_k of the capital stock if realized.⁴ Therefore the law of capital accumulation is given by

$$K_{t+1} = \left\{ (1 - \delta_t) K_t + \left[1 - S \left(\frac{I_t}{I_{t-1}} \right) \right] I_t \right\} (1 - x_{t+1} b_k) \quad (4.3)$$

where $\delta_t = \delta u_t^\eta$ is the depreciation rate increasing with capital utilization (Burnside and Eichenbaum, 1996), and $S = \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2$ is a capital adjustment cost function which verifies the usual properties ($S(0) = 0$, $S'(0) = 0$, and $S''(.) > 0$). The disaster is captured by the indicator x_{t+1} which is equal to 1 with probability θ_t and equal to 0 otherwise. This means that at time t agents know that in the next period disaster will happen ($x_{t+1} = 1$) with probability θ_t and with probability $1 - \theta_t$ there will be no disaster ($x_{t+1} = 0$). So far we have an indicator variable which stands for the occurrence of a disaster. In order to solve with linear approximations and the usual perturbation methods we need to introduce certainty equivalence. Therefore we replace the effective occurrence of a disaster by its expectation so that

⁴ As a disaster lowers the return on capital because investing in capital is riskier one can equally consider ex ante that this is the price or the quantity of capital which is affected by the disaster.

the law of accumulation of capital is rewritten as

$$\begin{aligned} K_{t+1} &= \theta_t \{(1 - \delta_t)K_t + [1 - S(I_t/I_{t-1})]I_t\} (1 - b_k) + \\ &\quad + (1 - \theta_t) \{(1 - \delta_t)K_t + [1 - S(I_t/I_{t-1})]I_t\} = \\ &= (1 - \theta_t b_k) \{(1 - \delta_t)K_t + [1 - S(I_t/I_{t-1})]I_t\} \end{aligned}$$

Hence the disaster risk is formally treated as a small but certain periodic depreciation shock here instead of a large uncertain shock. We plan to use projection methods in the following versions of this paper so as to solve the model while keeping the indicator variable.

In this model we analyze the response of the macroeconomic quantities when there is small increase in the probability that the disaster arrives in the next period. (Gourio, 2012) argues that the probability of disaster can be considered as strict rational expectations or more generally account for time-varying beliefs which may differ from the objective probability.⁵ We consider that the log of the probability of disaster follows a first-order autoregressive process as

$$\log \theta_t = (1 - \rho_\theta) \log \bar{\theta} + \rho_\theta \log \theta_{t-1} + \sigma_\theta \varepsilon_{\theta_t} \quad (4.4)$$

and assume that the shocks θ_{t+1} and x_{t+1} are independent, conditional on θ_t , in line with the evidence that a disaster occurrence tomorrow is not likely if there is a disaster today (Gourio, 2008).

We relax (Gourio, 2012)'s assumption that total factor productivity is reduced by exactly the same amount than the capital (b_k) in case of a disaster here. This assumption has been made for two reasons. First, detrending the capital by the (stochastic) technology level gives a stationary variable and reduces the dimension of the state space, so as to obtain analytical results and simplify the numerical analysis. Second, it delivers an empirically relevant magnitude for the recession. However, the combination of adjustment costs and monopolistic competition allows us to replicate a large enough fall in output following a rise in disaster risk without having to maintain this assumption here.

⁵Building on the behavioral macroeconomics literature would help to disentangle whether this probability is objective or stemming from agents' sentiments or "animal spirits" (waves of optimism or pessimism) but this is out of the scope of our paper for now (see Section 4.5).

Moreover, while Gourio argues that some disasters were associated with a fall in TFP (South America since 1945, Russia in 1917), some papers find, on the contrary, that TFP may rise in recessions as the least productive firms are shut down (for instance Petrosky-Nadeau, 2010).

Maximizing (1) subject to (2), (3), and (4) gives standard first-order conditions for consumption, labor, and the riskfree bonds, respectively as

$$\lambda_t = (C_t - hC_{t-1})^{-\gamma} - \beta h E_t (C_{t+1} - hC_t)^{-\gamma} \quad (4.5)$$

$$\chi L_t^\phi = w_t \lambda_t \quad (4.6)$$

$$\lambda_t = \beta E_t \lambda_{t+1} (1 + i_t) (1 + \pi_{t+1})^{-1} \quad (4.7)$$

in which λ_t is the Lagrange multiplier on the budget constraint (the marginal utility of consumption) and π is the inflation rate ($1 + \pi_{t+1} \equiv \frac{p_{t+1}}{p_t}$). The first-order conditions for capital and capital utilization are both affected by the disaster probability and the disaster size effect, $\theta_t b_k$, as follows⁶

$$\mu_t = \beta E_t [\lambda_{t+1} R_{t+1}^k u_{t+1} + \mu_{t+1} (1 - \delta u_{t+1}^\eta) (1 - \theta_{t+1} b_k)] \quad (4.8)$$

$$\lambda_t R_t^k = \mu_t \delta \eta u_t^{\eta-1} (1 - \theta_t b_k) \quad (4.9)$$

where μ_t is the Lagrange multiplier on the capital accumulation constraint (the shadow value of having an extra unit of capital).

Finally the first-order condition on investment, also affected by the

⁶These expressions hold under certainty-equivalence, such that disaster risk is not an *uncertainty* shock in this version of the paper. See Section 4.5 and Appendix.

disaster risk, is

$$\lambda_t = \mu_t (1 - \theta_t b_k) \left[1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \tau \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta E_t \mu_{t+1} (1 - \theta_{t+1} b_k) \tau \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \quad (4.10)$$

Without investment adjustment cost ($\tau = 0$), the Euler equation would be

$$\beta E_t \frac{\lambda_{t+1}}{\lambda_t} = E_t \left\{ [R_{t+1}^k u_{t+1} + (1 - \delta_{t+1})] (1 - \theta_t b_k) \right\}^{-1}$$

and would further reduce to the standard Euler equation if the probability of disaster was equal to zero.⁷ This states that the marginal utility from consumption tomorrow λ_{t+1} will be greater than the marginal utility from consumption today λ_t if the probability θ_t drawn today that a disaster arrives tomorrow increases given that the disaster would destroy a share of capital tomorrow. Consumption may fall or rise on impact following a shock to the disaster risk depending on the value of the elasticity of intertemporal substitution (see Sections 4.3 and 4.4). Moreover, complete markets imply that there is a unique stochastic discount factor, denoted $Q_{t,t+1}$ such that

$$1 + i_t = (E_t Q_{t,t+1})^{-1} \quad (4.11)$$

If $\tau = 0$, we can easily derive, from the first-order condition on bonds and the Euler equation above, that

$$E_t Q_{t,t+1} = E_t \left\{ (1 + \pi_{t+1}) [R_{t+1}^k u_{t+1} + (1 - \delta_{t+1})] (1 - \theta_t b_k) \right\}^{-1}$$

such that the stochastic discount factor also accounts for the disaster risk, while remains standard if $\theta_t = 0$.⁸

The existence of a risk of disaster on capital also affects the level of the Tobin's q. Defined as the ratio of the market value of one additional unit of investment to the marginal replacement cost of installed capital,⁹ it is given by the ratio of the Lagrange multipliers on (3) and

⁷For the purpose of the quantitative exercise, we keep adjustment costs positive ($\tau > 0$) though, in order to get a more gradual response of investment to changes in the probability of disaster, without qualitative impact on the Euler equation.

⁸Our time-varying stochastic discount factor however differs from (Gourio, 2012)'s because we do not assume that total factor productivity is reduced by the same amount than the capital stock in case of a disaster.

⁹In microeconomic terms, the ratio of the marginal benefit in terms of utility of an extra unit of investment over

(4), that is,

$$q_t = \frac{\mu_t}{\lambda_t} \quad (4.12)$$

Without disaster risk, the first-order condition on investment would imply that, in steady-state, $\bar{\lambda} = \bar{\mu}$, and thus $\bar{q} = 1$. Therefore whenever $q_{t+s} > 1$ in any period $t + s$ more investment would then add to the value of the firm, whereas with $q_{t+s} < 1$ it would be optimal for firms to disinvest. Here the disaster risk implies that $\bar{\lambda} = \bar{\mu}(1 - \bar{\theta}b_k)$, and thus

$$\bar{q} = \frac{1}{1 - \bar{\theta}b_k} > 1 \quad \text{if} \quad \bar{\theta} > 0$$

The higher the probability of disaster in steady-state, the higher the Tobin's q: the threshold value for (dis-)investment incentives is higher in the presence of a disaster risk. This is because a rise in disaster risk today leads to a higher marginal replacement cost of capital tomorrow, associated with a rise in the threshold level of investment that is required to increase firms' net market value.

4.2.2 Firms

The production block is roughly similar to the New Keynesian literature,¹⁰ except that we will allow the price adjustment to depend on the disaster risk. Production is split into a monopolistic competition market producing intermediate goods and a competitive sector producing the final consumption good as a CES composite of the intermediate goods.

4.2.2.1 Final goods producers

With intermediate goods indexed by j over a continuum of unit interval, the aggregate is given by

the marginal benefit in terms of utility of sacrificing a unit of current consumption in order to have an extra unit of investment.

¹⁰See for instance Fernández-Villaverde and Rubio-Ramírez (2006)

$$Y_t = \left(\int_0^1 Y_{j,t}^{\frac{\nu-1}{\nu}} dj \right)^{\frac{\nu}{\nu-1}}$$

which corresponds to a downward sloping demand curve for each good j as

$$Y_{j,t} = \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} y_t$$

and to an aggregate price index given by

$$p_t = \left(\int_0^1 p_{j,t}^{1-\nu} dj \right)^{\frac{1}{1-\nu}}$$

4.2.2.2 Intermediate goods producers

Intermediate goods are produced with capital and labor, according to a standard Cobb-Douglas production function

$$Y_{j,t} = A_t \tilde{K}_{j,t}^\alpha L_{j,t}^{1-\alpha}$$

in which the capital leased to the firms is

$$\tilde{K}_t = u_t K_t \tag{4.13}$$

where u_t is the variable utilization rate of capital, and in which total factor productivity, denoted A_t , is driven by

$$\log A_t = (1 - \rho_A) \log \bar{A} + \rho_A \log A_{t-1} + \sigma_A \varepsilon_{A_t} \tag{4.14}$$

where the shocks are small and normally distributed (ε_t is i.i.d. $N(0, 1)$).

There is a two-step problem for firms producing the intermediate goods. First, each firm j minimizes capital and labor costs at each date, independently of price adjustment, subject to the restriction of producing at least as much as the intermediate good is demanded at the selling price, that is,

$$\min_{L_{j,t}, \tilde{K}_{j,t}} p_t (w_t L_{j,t} + R_t^k \tilde{K}_{j,t})$$

$$\text{s.t. } A_t \tilde{K}_{j,t}^\alpha L_{j,t}^{1-\alpha} \geq \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} Y_t$$

The first-order conditions for this problem give a capital-labor ratio which holds at the aggregate level since it is the same across all firms

$$\left(\frac{\tilde{K}_{j,t}}{L_{j,t}} \right)^* = \frac{w_t}{R_t^k} \frac{\alpha}{(1-\alpha)}$$

and allows to write the optimal marginal input costs as

$$mc_t^* = w_t^{1-\alpha} \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{\alpha} \right)^\alpha \frac{R_t^\alpha}{A_t}$$

from which the aggregate first-order conditions are expressed as

$$w_t = mc^* (1-\alpha) A_t \left(\frac{\tilde{K}_t}{L_t} \right)^\alpha \quad (4.15)$$

$$R_t^k = mc^* \alpha A_t \left(\frac{\tilde{K}_t}{L_t} \right)^{\alpha-1} \quad (4.16)$$

Then, given the optimal input mix, some firms maximize their profits by choosing their selling price $p_{j,t}$. We consider two alternative ways to introduce nominal stickiness. One is standard Calvo time-dependent pricing so that firms in the intermediate sector face a constant probability ζ_0 of being unable to change their price at each time t despite the disaster risk. The other one is to assume that firms' price adjustment increases in the aggregate risk, *i.e.* the gap between the current value of the probability ζ_t of being unable to change one's price and the Calvo probability ζ_0 is given by

$$\zeta_t - \zeta_0 = -\theta_t^\iota$$

where ι is the elasticity of the gap to the probability of disaster.¹¹ ¹²

¹¹Note that this function requires to impose a parameter restriction so that ζ remains positive. With $\bar{\theta} = 0.01$ in particular, ι cannot be lower than 0.05.

¹²This price setting reminds the 'SS pricing' literature Caplin and Leahy (1991) although the firms do not react to

Writing ζ as standing either for ζ_0 in the first case or for ζ_t in the second, the profit-maximizing problem in both cases is

$$\max_{p_{j,t}} E_t \sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} \left(\left(\frac{p_{j,t}}{p_{t+s}} \right)^{1-\nu} y_{t+s} - mc_{t+s}^* \left(\frac{p_{j,t}}{p_{t+s}} \right)^{-\nu} y_{t+s} \right)$$

The solution to this problem holds for all optimizing firms, independently of j ($p_t^* = p_{j,t}^*$). The gap between the optimal (reset) price p_t^* and the consumer price index p_t is

$$\frac{p_t^*}{p_t} = \frac{\nu}{\nu-1} E_t \frac{\sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} \left(\frac{p_{t+s}}{p_t} \right)^\nu Y_{t+s} m c_{t+s}^*}{\sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} \left(\frac{p_{t+s}}{p_t} \right)^{\nu-1} Y_{t+s}}$$

This expression can finally be rewritten recursively in terms of an inflation gap to allow for a non-zero inflation steady-state, such that

$$\frac{1 + \pi_t^*}{1 + \pi_t} = \frac{\nu}{\nu-1} E_t \frac{\Xi_{1_t}/p_t^\nu}{\Xi_{2_t}/p_t^{\nu-1}} \quad (4.17)$$

with $\pi_t = \frac{p_t}{p_{t-1}} - 1$ the inflation rate, π_t^* the reset inflation rate, and

$$\frac{\Xi_{1_t}}{p_t^\nu} = \frac{Q_{t+s}}{\beta} Y_t m c_t^* + \zeta \beta E_t \frac{\Xi_{1_{t+1}}}{p_{t+1}^\nu} (1 + \pi_{t+1})^\nu, \quad \text{and} \quad (4.18)$$

$$\frac{\Xi_{2_t}}{p_t^{\nu-1}} = \frac{Q_{t+s}}{\beta} Y_t + \zeta \beta E_t \frac{\Xi_{2_{t+1}}}{p_{t+1}^{\nu-1}} (1 + \pi_{t+1})^{\nu-1} \quad (4.19)$$

All the computational details are given in Appendix.

4.2.3 Public authority

The public authority consumes some output G_t , charges lump sum taxes T_t to households, and issues debt D_t which pays interest i_t set up according to a standard Taylor-type rule that depends on the deviation

the effective realization of aggregate shocks but to the expected risk. This is because the probability of disaster is incorporated in the forward-looking agents' optimization problem and the size of an effective disaster is constant here.

of inflation from steady-state and on an output growth gap as

$$i_t = \rho_i i_{t-1} + (1 - \rho_i) [\psi_\pi (\pi_t - \bar{\pi}) + \psi_Y (y_t - \bar{y}) + \bar{i}] + \sigma_i \varepsilon_{i_t} \quad (4.20)$$

in which y is the growth rate of output and where an overbar indicates the steady-state value of a variable. The public authority's budget constraint equates spending plus payment on existing debt to collected taxes plus new debt issuance¹³, that is,

$$G_t + (1 + i_t) \frac{D_t}{p_t} = T_t + \frac{D_{t+1}}{p_t}$$

in which G_t follows a first-order autoregressive process in the logs

$$\log G_t = (1 - \rho_G) \log(\omega \bar{Y}) + \rho_G \log G_{t-1} + \sigma_G \varepsilon_{G_t} \quad (4.21)$$

where ω is the steady-state share of output devoted to public expenditures.

4.3 Equilibrium

4.3.1 Market clearing

Market-clearing in the bond market implies that the total amount of debt is equal to the total amount of bonds in period t

$$D_t = B_t$$

and market-clearing in output implies that

$$Y_t = C_t + I_t + G_t \quad (4.22)$$

Moreover, knowing the demand for individual intermediate goods firms, we are able to derive the aggregate production function as a function of the individual firms' production function and a measure of

¹³We assume that there is no money, hence no seigniorage revenue in the model.

the inefficiency introduced by the dispersion in relative prices, $\Omega_t = \int_0^1 \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} dj$, such that

$$Y_t = \frac{A_t \tilde{K}_t^\alpha L_t^{1-\alpha}}{\Omega_t} \quad (4.23)$$

in which the aggregate price dispersion is given by the recursive equation

$$\Omega_t = (1 - \zeta) \left(\frac{1 + \pi_t}{1 + \pi_t^*} \right)^\nu + \zeta (1 + \pi_t)^\nu \Omega_{t-1} \quad (4.24)$$

Finally, given that a fraction ζ of firms do not readjust their prices, the aggregate price index, $p_t^{1-\nu} = \int_0^1 p_{j,t}^{1-\nu} dj$, is given by $p_t^{1-\nu} = (1 - \zeta)p_t^{*1-\nu} + \zeta p_{t-1}^{1-\nu}$, further rewritten in inflation terms as

$$(1 + \pi_t)^{1-\nu} = (1 - \zeta)(1 + \pi_t^*)^{1-\nu} + \zeta \quad (4.25)$$

Equilibrium is characterized by equations (3) to (25) in 23 unknowns: $\{Y, C, I, G, A, L, K, \tilde{K}, u, w, R^k, \Omega, \pi, \pi^*, \tilde{\Xi}_1, \tilde{\Xi}_2, mc^*, \lambda, \mu, i, q, Q, \theta\}$.

4.3.2 Calibration and steady-state analysis

Our calibration, summarized in Table 1, is mostly based on the standard New Keynesian literature (Smets and Wouters, 2003, Rudebusch and Swanson, 2008). In particular the value of the inverse of the elasticity of intertemporal substitution (EIS) ranges from 0.5 to 6 under CRRA preferences with a baseline value of 2. In addition, Barro (2006) found on historical data that the average share of capital that is destroyed in case of disaster is 43%, while (Gourio, 2012) estimates that the average probability of a such a disaster is 1.7% annually, backing it out from evidence on asset prices under the assumption that the fall in total factor productivity is also exactly equal to 43%. Since we use the quarterly calibration of standard New Keynesian models and are not able to replicate the estimation so far, we test for several values of $\bar{\theta}$ around a 1% benchmark, as well as for several values of b_k and of the persistence in the shock to θ , without significant changes in our results.

In the steady-state, the capital stock, output, and consumption are lower in the presence of a disaster risk as compared to the same economy without disaster for all values of risk aversion/EIS. Steady-state investment and labor may be larger in the presence of disasters if the EIS is very high ($\gamma = 0.5$), but are generally weaker, such that wages are generally lower. The firms can substitute labor to capital such that their steady-state marginal costs are unchanged even though the cost of capital is higher in case of disaster. Therefore the non-zero steady-state inflation rate is unaffected by disaster risk and equal to the public authority's target that we set at 2% annually. The main ratios, C/Y , I/Y , G/Y are in all cases slightly above or below their standard values, 60%, 20% and 20%, respectively. Finally, the steady-state risk premium in case of disaster corresponds to the wedge between the higher steady-state return on capital and the unchanged risk-free rate.

(Gourio, 2012) found that the model quantities shift to a lower steady-state in the economy with disaster risk (as compared to an economy where the disaster risk does not exist) if and only if the EIS is larger than unity. Therefore, it is noteworthy to clarify at this point why we do get a lower steady-state for all values of the EIS here, on the one hand, and its further implications for the model dynamics, on the other hand. First, with Epstein-Zin preferences, *i.e.* dissociating the risk aversion coefficient from the inverse of the EIS, it would be possible to show that, when investment in capital becomes riskier, the *risk-adjusted* return on capital goes down for risk averse agents, while the effect of this change on the consumption-savings decisions depends on the value of the EIS (Weil, 1990, Angeletos, 2007). In particular, when the EIS is larger than unity ($\gamma < 1$), the substitution effect of a higher risk-adjusted return is larger than the income effect and savings fall. Therefore the steady-state capital stock and output are lower. However, when the EIS is equal to 1, both effects cancel each other out and savings are unaffected by changes in the risk-adjusted return, that is, are unaffected by changes in the return on capital even if agents are risk-averse.¹⁴ Our specification, where risk aversion is only the inverse of the EIS, does not allow to disentangle the two effects, yet remains preferable in order to solve the equity premium puzzle

¹⁴The EIS determines the *sign* of the effect of increased uncertainty on savings while the risk aversion only affects its *magnitude* (Weil, 1990).

by incorporating habit formation (Weil, 1989, Uhlig, 2007, Angeletos, 2007).

More importantly, the reason why we get lower steady-state macro quantities even when the EIS is unity is because we solve the model such that the disaster risk is treated as a small but certain probability of disaster instead of being a large uncertain shock. This allows to solve the model quite easily without having to maintain Gourio's assumption that the disaster is a strict combination of a depreciation shock to capital and a negative shock to the total factor productivity by the same amount. Meanwhile, this does not substantially restrict our business cycle analysis for two reasons. First, we capture the main first-moment effect of disaster risk by the fact that depreciation of capital will be higher in the future, even though we do not have the second-moment effect associated with higher uncertainty about future depreciation.¹⁵ Second, Gourio shows that Tallarini (2000)'s *observational equivalence* in the dynamics of the macroeconomic variables in case there is an aggregate risk or not does not hold when the probability of disaster is not constant. When the disaster risk is time-varying, Gourio finds that risk aversion matters for the macroeconomic dynamics, and this is captured here.

4.4 Impulse responses of the macroeconomic variables

Analyzing the effects of a time-varying risk on asset pricing would require to treat the disaster risk as an uncertainty shock and to use nonlinear methods to solve the model. However, since there is a consensus about the irrelevance of approximation beyond the first-order for the macroeconomic quantities, on the one hand, and given that we do not consider the case of a large shock, on the other hand, we maintain certainty-equivalence and first-order methods in this version of the paper, although we keep track of some second-order corrections in the Appendix.¹⁶¹⁷ For each (small) shock below, we compare the responses obtained in our model (solid line) to their counterpart

¹⁵Gourio admits that the two effects are present but cannot be disentangled in his article. In every case, both effects push the variables in the same direction, and the first-moment effect is far more important for macroeconomic quantities.

¹⁶Since certainty-equivalence holds, these correction terms are naturally very small.

¹⁷The effective occurrence of a disaster would be a large shock, whereas the rise in the probability of disaster considered here is a small one.

in a flexible-price but otherwise similar model¹⁸ (dashed line) and in a standard sticky-price New Keynesian model without disaster risk (dotted line).

4.4.1 A rise in the probability of disaster

Figure 1 depicts the responses of the main variables to a rise in the probability of disaster, θ . Investment and capital fall on impact as households foresee the upcoming depreciation of capital when the probability of disaster, θ , rises. These effects are much more important under Calvo price stickiness ($\zeta = 0.8$) than under flexible prices ($\zeta = 0$) as all firms do not adjust their prices downwards as much as they would optimally do to match the fall in aggregate demand. The capital stock still goes down next periods because of the depressed investment even though the probability of disaster gradually returns to its initial level (from the autoregressive process).

Labor supply decreases when prices are flexible because it is less attractive for workers to work today when the return on savings is low (intertemporal effect), despite a negative wealth effect that tends to push employment up.¹⁹ Wages thus slightly rise. However, when prices are sticky, the firms that cannot readjust their prices downwards as much as they want face an even lower demand for their own intermediate goods, and thus in turn lower their demand of labor, leading wages to fall. Because capital and labor decrease more under sticky prices, combined with the fact that decrease in aggregate demand is more severe, the slump in output is far larger with nominal rigidity.

In the flexible case, consumption increases on impact as households substitute consumption for investment in the first period, while lower output leads consumption to fall in the next periods, for standard values of the EIS and/or risk aversion.²⁰ With sticky prices however, consumption falls on impact for the baseline calibration ($\gamma = 2$), or lower values of the EIS (higher risk aversion). For very low risk aversion, consumption moves up on impact similarly to the flexible-price

¹⁸The flexible-price model is different from Gourio's RBC with disaster risk since we have CRRA preferences with habit formation, a public authority, and variable utilization rate of capital, on the one hand, and because we do not assume a fall in TFP by the same amount as simultaneous to the rise in the probability of disaster, on the other hand.

¹⁹The relative importance of the two effects would depend on the EIS with Epstein-Zin preferences. However this result is familiar with standard calibration of CRRA preferences.

²⁰Gourio (2012) found a similar effect with a slightly different flexible-price model and a simultaneous shock to the TFP.

case but a quantitative difference due to price stickiness remains, as shown in Figure 5.

As investment in capital is riskier, households' demand for safer government bonds rises, so that the short-term nominal interest rate falls ("flight to quality" effect). However, because of the inertia in the Taylor-type reaction, the interest rate — and therefore inflation — falls less under price stickiness. Finally, actual inflation decreases less than reset inflation, so that the price dispersion falls, but still falls more than the nominal interest rate, so that the real rate rises.

Figures 6 to 10 present some robustness checks and alternative specifications. Figure 6 considers different values of the steady-state probability of disaster ($\bar{\theta}$). While the magnitude of the effects increases in the steady-state disaster risk, the qualitative responses are all identical. Figure 7 gives some alternative values for the persistence of the shock (ρ_θ). Figure 8 tests for different values for the share of capital which is destroyed in case of disaster (b_k), including a possible negative value.²¹

More importantly, Figure 9 gives the responses under state-dependent price stickiness for different values of the parameter $\iota < 1$.²² The responses still differ significantly from the pure flexible-price version of the model ($\zeta = 0$) and our main results hold, notably the drop in wages, including for an extreme $\iota = 0.1$.

We finally consider a fall in the probability of disaster in Figure 10. Table 2 gives the second-order correction terms associated with this shock, naturally found to be very small under the certainty-equivalence assumption.

To sum up, a rise in the probability of disaster creates a recession, a fall in inflation, a flight to quality in terms of asset demand, depressed investment and labor, as well as lower consumption for standard risk aversion. The fact that the probability of a disaster is higher suffices to generate this recession, without effective occurrence of the disaster.

²¹A negative value of b_k verifies that the model works symmetrically such that the rare event could be a "miracle" instead of a "disaster".

²²When $\iota \geq 1$, the responses are almost identical to the time-dependent pricing case.

4.4.2 Standard shocks

The responses to standard shocks in the model with disaster risk are very close to the responses in a standard New Keynesian model.

For a TFP shock (Figure 2), output and investment rise because the marginal returns on labor and capital rise. However this is slightly less important in the presence of a disaster risk which depreciates capital. Consumption rises more however from the substitution effect between investment and consumption for households. The response of labor is discussed extensively in the literature: in opposition to a RBC where labor increases because the marginal return on labor is higher, sticky prices prevent some firms from lowering their prices leading them to lower their labor demand because of the contraction in demand for their own intermediate goods (Gali, 1999). In addition, higher incomes for households make leisure more desirable so that the supply of labor does not substantially rise either. As reset inflation is higher than actual inflation, price dispersion falls and the real interest rate goes up despite the fall in the nominal rate.

A positive shock to public expenditures (Figure 3) also replicates the very well-known reactions. In all cases, there is a temporary rise in output from the rise in aggregate demand, an eviction effect on private consumption and investment, hence a fall in capital. Thus firms rely more on labor and wages go up. High reset inflation creates more price dispersion, and the nominal rate is increased.

Finally, a monetary contraction (Figure 4) generates the standard decrease in all macro quantities, as well as in inflation and price dispersion.

4.5 Further research

This paper provides a baseline framework that could be used to develop a number of innovative research ideas, including the role of monetary policy to prevent self-fulfilling recessions in case of misperceptions about the disaster risk. This Section presents our research agenda, which broadly consists in three steps.

First, we would like to account for a *perceived* risk of disaster along with the *real* disaster risk. (Gourio, 2012) considers that the prob-

ability of disaster introduced in his model (and in ours) may result from the economic agents' perception, probably because considering that the probability taken as given by the agents is the real risk would be associated with perfect individual rationality and knowledge about disasters while one could be more agnostic by considering it as merely perceived, especially for *rare* events. We think that it would be helpful to build on the behavioral macroeconomics literature (Gabaix and Laibson, 2002, De Grauwe, 2010, Fuster et al., 2010, Angeletos and La’O, 2012, Barsky and Sims, 2012) in order to disentangle a *perceived* from a *real* disaster risk. Another mean would be the use of computational methods in order to keep the disaster variable (x_{t+1}) as an indicator in the Euler equation instead of substituting the time-varying probability θ_t of an effective future occurrence. This would allow to simulate a rise in the probability of disaster while preventing the real occurrence of a disaster by accounting for uncertainty in the model.

As a second step, we will evaluate the model predictions in terms of asset pricing, especially the countercyclical of the risk premium. Some interactions between price rigidity and the risk of disaster may affect equity returns. The asset price volatility may in turn have important consequences on consumption volatility. In particular the perception of disaster risk may be one of the psychological mechanisms that alter the reactivity of consumption changes to asset price movements (see Lynch, 1996, or Gabaix and Laibson, 2002, for instance), in addition to habit formation (Campbell and Cochrane, 1999, Uhlig, 2007), or adjustment costs (Grossman and Laroque, 1990). On practical grounds, pricing assets requires a few more sophistications in our setup. One is to go beyond the first-order approximation in the Taylor expansion. The consensus in the literature is that these higher-order terms do not matter for the responses of macroeconomic quantities we have focused on so far but have an important role in the asset pricing in the presence of a time-varying risk. Another key element will be to add corporate bonds in the model since leverage is a standard way to make equity returns more volatile and procyclical — in line with the data — in the literature, which may be even more relevant in a model in which firms' prices are sticky.

Finally, we would like to assess the desirability of monetary policy to

prevent a (self-fulfilling) recession from a sudden rise in the (perceived) probability of disaster. Several conventional and unconventional interventions could be compared with one another by incorporating a welfare function measuring their effectiveness. In particular we think of adding an extra term in the Taylor-type rule which would represent a direct response of the monetary authority in the face of a wave of pessimism. This would be a quasi-conventional intervention, making changes in the nominal interest rate more reactive but still limited by the zero lower bound. A more unconventional measure could consist in purchasing corporate bonds (which may encompass bank debt), directly affected by the disaster risk, by selling riskfree government bonds (as far as sovereign default is excluded).

4.6 Conclusion

This paper provides a baseline framework to analyze the business cycle responses of macroeconomic quantities in the presence of a small time-varying disaster risk in an otherwise standard New Keynesian model. While following Gourio (2012) on the description of an economic disaster, we relax the assumption that total factor productivity needs to fall by the same amount than the capital stock in case of a disaster. By incorporating investment adjustment costs and monopolistic competition, we show that the magnitude of the recession following a shock to the probability of disaster may be far increased. As compared with the early papers on rare events, we also account for the fact that consumption and wages do not rise in distressed economic times, whether nominal rigidity is time-dependent or state-dependent. More generally, this paper is a first step towards the introduction of rare events into the models used to conduct monetary policy, and will be used to compare the effectiveness of several interventions in the presence of such a risk.

4.7 Appendix

A1. Households

Given that next period disaster x_{t+1} is equal to 1 with probability θ_t and equal to 0 with probability $1 - \theta_t$, the law of accumulation of

capital can be rewritten as

$$K_{t+1} = [\theta_t(1 - b_k) + (1 - \theta_t)]\{(1 - \delta_t)K_t + [1 - S(I_t/I_{t-1})]I_t\}$$

$$= (1 - \theta_t b_k)\{(1 - \delta_t)K_t + [1 - S(I_t/I_{t-1})]I_t\}$$

Therefore the Lagrangian for the households' problem is

$$\begin{aligned} \mathcal{L} = & E_t \sum_{t=0}^{\infty} \beta^t \left\{ \left(\frac{(C_t - hC_{t-1})^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\phi}}{1+\phi} \right) \right. \\ & + \lambda_t \left(W_t L_t + (1+i_{t-1}) \frac{B_t}{p_t} + \frac{M_t}{p_t} - \frac{B_{t+1}}{p_t} - \frac{M_{t+1}}{p_t} + R_t^k u_t K_t + \Pi_t - T_t - I_t - C_t \right) \\ & \left. + \mu_t \left[\left((1 - \delta u_t^\eta) K_t + \left(1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) I_t \right) (1 - \theta_t b_k) - K_{t+1} \right] \right\} \end{aligned}$$

and the first-order conditions are

- Consumption: $\lambda_t = (C_t - hC_{t-1})^{-\gamma} - \beta h E_t (C_{t+1} - hC_t)^{-\gamma}$
- Labor: $\chi L_t^\phi = w_t \lambda_t$
- Bonds: $\lambda_t = \beta E_t \lambda_{t+1} (1 + i_t) (1 + \pi_{t+1})^{-1}$, with $1 + \pi_{t+1} \equiv \frac{p_{t+1}}{p_t}$
- Capital: $\mu_t = \beta E_t [\lambda_{t+1} R_{t+1}^k u_{t+1} + \mu_{t+1} (1 - \delta u_{t+1}^\eta) (1 - \theta_{t+1} b_k)]$
- Capital utilization rate: $\lambda_t R_t^k = \mu_t \delta \eta u_t^{\eta-1} (1 - \theta_t b_k)$
- Investment: $\lambda_t = \mu_t (1 - \theta_t b_k) \left[1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \tau \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right]$
 $+ \beta E_t \mu_{t+1} (1 - \theta_{t+1} b_k) \tau \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2$

With no investment adjustment cost ($\tau = 0$), the FOC on investment becomes $\lambda_t = \mu_t (1 - \theta_t b_k)$, which in turn implies from the FOC on the capital utilization rate that $R_t^k = \delta'_t$. Substituting into the FOC on capital gives the Euler equation (11) in case $\tau = 0$.

A2. Firms

- Production aggregation

The aggregate of intermediate goods is given by

$$Y_t = \left(\int_0^1 Y_{j,t}^{\frac{\nu-1}{\nu}} dj \right)^{\frac{\nu}{\nu-1}}$$

so that the profit maximization problem of the representative firm in the final sector is

$$\max_{Y_{t,j}} p_t \left(\int_0^1 Y_{j,t}^{\frac{\nu-1}{\nu}} dj \right)^{\frac{\nu}{\nu-1}} - \int_0^1 p_{j,t} Y_{j,t} dj$$

The first-order condition with respect to $Y_{t,j}$ yields a downward sloping demand curve for each intermediate good j as

$$Y_{j,t} = \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} Y_t$$

The nominal value of the final good is the sum of prices times quantities of intermediates

$$p_t Y_t = \int_0^1 p_{j,t} Y_{j,t} dj$$

in which Y_t is substituted to give the aggregate price index as

$$p_t = \left(\int_0^1 p_{j,t}^{1-\nu} dj \right)^{\frac{1}{1-\nu}}$$

- Cost minimization

Firms are price-takers in the input markets, facing a nominal wage $w_t p_t$ and a nominal rental rate $R_t^k p_t$ (w_t and R_t^k are in real terms). Therefore, they choose the optimal quantities of labor and capital given the input prices and subject to the restriction of producing at least as much as the intermediate good is demanded at the given price. The intratemporal problem is

$$\min_{L_{j,t}, \tilde{K}_{j,t}} w_t p_t L_{j,t} + R_t^k p_t \tilde{K}_{j,t}$$

$$\text{s.t. } a_t \tilde{K}_{j,t}^\alpha L_{j,t}^{1-\alpha} \geq \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} Y_t$$

The first-order conditions are

$$(L_{j,t} :) \quad w_t = \frac{\varphi_{j,t}}{p_t} (1 - \alpha) A_t \left(\frac{\tilde{K}_{j,t}}{L_{j,t}} \right)^\alpha$$

$$(\tilde{K}_{j,t} :) \quad R_t^k = \frac{\varphi_{j,t}}{p_t} \alpha A_t \left(\frac{\tilde{K}_{j,t}}{L_{j,t}} \right)^{\alpha-1}$$

in which the Lagrange multiplier $\varphi_{j,t}$ can be interpreted as the (nominal) marginal cost associated with an additional unit of capital or labor. Rearranging gives the optimal capital over labor ratio as

$$\left(\frac{\tilde{K}_{j,t}}{L_{j,t}} \right)^* = \frac{w_t}{R_t^k} \frac{\alpha}{(1 - \alpha)}$$

in which none of the terms on the right hand side depends on j , and thus holds for all firms in equilibrium, *i.e.*, $\frac{\tilde{K}_t}{L_t} = \frac{\tilde{K}_{j,t}}{L_{j,t}}$. Replacing in the first-order conditions further gives $mc_t^* = \frac{\varphi_t}{p_t}$ as

$$mc_t^* = w_t^{1-\alpha} \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{\alpha} \right)^\alpha \frac{(R_t^k)^\alpha}{A_t}$$

- Profit maximization

Let us now consider the pricing problem of a firm that gets to update its price in period t and wants to maximize the present discounted value of future profits. First, the (nominal) profit flow, $p_{j,t} Y_{j,t} - w_t p_t L_{j,t} - R_t^k p_t \tilde{K}_{j,t}$, can be rewritten as $\Pi_{j,t} = (p_{j,t} - \varphi_t) Y_{j,t}$, that is, in real terms, $\frac{\Pi_{j,t}}{p_t} = \frac{p_{j,t}}{p_t} Y_{j,t} - mc_t^* Y_{j,t}$. Firms will discount future profit flows by both the stochastic discount factor, $Q_t = \beta^s \lambda_{t+s}$, and by the probability ζ^s that a price chosen at time t is still in effect at time s . Replacing $Y_{j,t} = \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} Y_t$, the profit maximization problem is

$$\max_{p_{j,t}} E_t \sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} \left(\left(\frac{p_{j,t}}{p_{t+s}} \right)^{1-\nu} Y_{t+s} - mc_{t+s}^* \left(\frac{p_{j,t}}{p_{t+s}} \right)^{-\nu} Y_{t+s} \right)$$

Given that $mc_t^* = \frac{\varphi_t}{p_t}$ and factorizing, we can rewrite it as

$$\max_{p_{j,t}} E_t \sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} p_{t+s}^{\nu-1} Y_{t+s} (p_{j,t}^{1-\nu} - \varphi_t p_{j,t}^{-\nu})$$

The first-order condition is

$$E_t \sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} p_{t+s}^{\nu-1} Y_{t+s} ((1-\nu)p_{j,t}^{-\nu} + \nu \varphi_t p_{j,t}^{-\nu-1}) = 0$$

which simplifies as

$$p_{j,t}^* = \frac{\nu}{\nu-1} E_t \frac{\sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} p_{t+s}^{\nu} Y_{t+s} m c_{t+s}^*}{\sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} p_{t+s}^{\nu-1} Y_{t+s}}$$

Note that this optimal price depends on aggregate variables only, so that $p_t^* = p_{j,t}^*$. The gap between the current price and the optimal aggregate price is thus given by

$$\frac{p_t^*}{p_t} = \frac{\nu}{\nu-1} E_t \frac{\sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} \left(\frac{p_{t+s}}{p_t}\right)^\nu Y_{t+s} m c_{t+s}^*}{\sum_{s=0}^{\infty} (\zeta)^s Q_{t+s} \left(\frac{p_{t+s}}{p_t}\right)^{\nu-1} Y_{t+s}}$$

In order to stress out the recursive price adjustment, let define p_t^* as

$$p_t^* = \frac{\nu}{\nu-1} E_t \frac{\Xi_{1_t}}{\Xi_{2_t}}$$

in which Ξ_{1_t} and Ξ_{2_t} can be expressed recursively as

$$\Xi_{1_t} = Q_{t+s} p_t^\nu Y_t m c_t^* + \zeta E_t \Xi_{1_{t+1}}$$

$$\Xi_{2_t} = Q_{t+s} p_t^{\nu-1} Y_t + \zeta E_t \Xi_{2_{t+1}}$$

and rewritten as

$$\beta \frac{\Xi_{1_t}}{p_t^\nu} = Q_{t+s} Y_t m c_t^* + \zeta \beta^2 E_t \frac{\Xi_{1_{t+1}}}{p_{t+1}^\nu} \left(\frac{p_{t+1}}{p_t} \right)^\nu$$

$$\beta \frac{\Xi_{2_t}}{p_t^{\nu-1}} = Q_{t+s} Y_t + \zeta \beta^2 E_t \frac{\Xi_{2_{t+1}}}{p_{t+1}^{\nu-1}} \left(\frac{p_{t+1}}{p_t} \right)^{\nu-1}$$

Therefore, we have

$$\frac{p_t^*}{p_t} = \frac{\nu}{\nu - 1} E_t \frac{\frac{\Xi_{1_t}}{p_t^\nu}}{\frac{\Xi_{2_t}}{p_t^{\nu-1}}}$$

A3. Aggregation

Bonds Market

Market-clearing requires that:

$$D_t = B_t$$

Aggregate Demand

First replace $D_t = B_t$ into the public authority's budget constraint, and express T_t as

$$T_t = G_t + (1 + i_t) \frac{B_t}{p_t} - \frac{B_{t+1}}{p_t}$$

which can be plugged into the household budget constraint as

$$C_t + I_t + \frac{B_{t+1}}{p_t} = w_t L_t + (1 + i_t) \frac{B_t}{p_t} + R_t^k \tilde{K}_t + \Pi_t - \left(G_t + (1 + i_t) \frac{B_t}{p_t} - \frac{B_{t+1}}{p_t} \right)$$

This further simplifies to:

$$C_t + I_t + G_t = w_t L_t + R_t^k \tilde{K}_t + \Pi_t$$

where we have to verify that the RHS is equal to Y_t . Total profits Π_t must be equal to the sum of profits earned by intermediate good firms, that is

$$\Pi_t = \int_0^1 \Pi_{j,t} dj$$

Real profits earned by intermediate good firms j are given by

$$\Pi_{j,t(\text{real})} = \frac{p_{j,t}}{p_t} Y_{j,t} - w_t L_{j,t} - R_t^k \tilde{K}_{j,t}$$

Substituting $Y_{j,t}$, we have

$$\Pi_{j,t(\text{real})} = \left(\frac{p_{j,t}}{p_t} \right)^{1-\nu} Y_t - w_t L_{j,t} - R_t^k \tilde{K}_{j,t}$$

Therefore,

$$\begin{aligned} \Pi_{t(\text{real})} &= \int_0^1 \left(\left(\frac{p_{j,t}}{p_t} \right)^{1-\nu} Y_t - w_t L_{j,t} - R_t^k \tilde{K}_{j,t} \right) dj = \int_0^1 \left(\frac{p_{j,t}}{p_t} \right)^{1-\nu} Y_t dj \\ &\quad - \int_0^1 w_t L_{j,t} dj - \int_0^1 R_t^k \tilde{K}_{j,t} dj \end{aligned}$$

$$\begin{aligned} \Pi_{t(\text{real})} &= \int_0^1 \left(\left(\frac{p_{j,t}}{p_t} \right)^{1-\nu} Y_t - w_t L_{j,t} - R_t^k \tilde{K}_{j,t} \right) dj = Y_t \frac{1}{p_t^{1-\nu}} \int_0^1 (p_{j,t})^{1-\nu} dj \\ &\quad - w_t \int_0^1 L_{j,t} dj - R_t^k \int_0^1 \tilde{K}_{j,t} dj \end{aligned}$$

Given that

- - the aggregate price level is $p_t^{1-\nu} = \int_0^1 p_{j,t}^{1-\nu} dj$,
- - aggregate labor demand must equal supply, $\int_0^1 L_{j,t} dj = L_t$, and
- - aggregate supply of capital services must equal demand $\int_0^1 \tilde{K}_{j,t} dj = \tilde{K}_t$,

the aggregate profit is

$$\Pi_{t(\text{real})} = Y_t - w_t L_t - R_t^k \tilde{K}_t$$

Plugging this expression into the household budget constraint finally gives the aggregate accounting identity as

$$Y_t = C_t + I_t + G_t$$

Inflation

Firms have a probability $1 - \zeta$ of getting to update their price each period. Since there are an infinite number of firms, there is also the exact fraction $1 - \zeta$ of total firms who adjust their prices and the fraction ζ who stay with the previous period price. Moreover, since there is a random sampling from the entire distribution of firm prices, the distribution of any subset of firm prices is similar to the entire distribution. Therefore, the aggregate price index, $p_t^{1-\nu} = \int_0^1 p_{j,t}^{1-\nu} dj$, is rewritten as

$$p_t^{1-\nu} = \int_0^{1-\zeta} p_t^{*1-\nu} dj + \int_{1-\zeta}^1 p_{j,t-1}^{1-\nu} dj$$

which simplifies to

$$p_t^{1-\nu} = (1 - \zeta)p_t^{*1-\nu} + \zeta p_{t-1}^{1-\nu}$$

Dividing both sides of the equation by $p_{t-1}^{1-\nu}$

$$\left(\frac{p_t}{p_{t-1}}\right)^{1-\nu} = (1 - \zeta) \left(\frac{p_t^*}{p_{t-1}}\right)^{1-\nu} + \zeta \left(\frac{p_{t-1}}{p_{t-1}}\right)^{1-\nu}$$

and defining gross inflation as $1 + \pi_t = \frac{p_t}{p_{t-1}}$ and gross reset inflation as $1 + \pi_t^* = \frac{p_t^*}{p_{t-1}}$, we get

$$(1 + \pi_t)^{1-\nu} = (1 - \zeta)(1 + \pi_t^*)^{1-\nu} + \zeta$$

Finally, from $p_t^* = \frac{\nu}{\nu-1} E_t \frac{\Xi_{1t}}{\Xi_{2t}}$, we have

$$\frac{p_t^*}{p_t} = \frac{\nu}{\nu-1} E_t \frac{\Xi_{1t}/p_t^\nu}{\Xi_{2t}/p_t^{\nu-1}}$$

Rewriting the left-hand side as $\frac{p_t^*}{p_t} \frac{p_{t-1}}{p_{t-1}}$, and rearranging, we get

$$\pi_t^* = \pi_t \frac{\nu}{\nu - 1} E_t \frac{\Xi_{1t}/p_t^\nu}{\Xi_{2t}/p_t^{\nu-1}}$$

Therefore we have

$$\frac{\Xi_{1t}}{p_t^\nu} = \frac{Q_{t+s}}{\beta} Y_t m c_t^* + \zeta \beta E_t \frac{\Xi_{1t+1}}{p_{t+1}^\nu} (1 + \pi_{t+1})^\nu$$

$$\frac{\Xi_{2t}}{p_t^{\nu-1}} = \frac{Q_{t+s}}{\beta} Y_t + \zeta \beta E_t \frac{\Xi_{2t+1}}{p_{t+1}^{\nu-1}} (1 + \pi_{t+1})^{\nu-1}$$

Aggregate Supply

We know that the demand to individual firm j is given by

$$Y_{j,t} = \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} Y_t$$

and that firm j hires labor and capital in the same proportion than the aggregate capital to labor ratio (common factor markets). Hence, substituting in the production function for the intermediate good j we get

$$A_t \left(\frac{\tilde{K}_t}{L_t} \right)^\alpha L_{j,t} = \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} Y_t$$

Then, summing up across the intermediate firms gives

$$A_t \left(\frac{\tilde{K}_t}{L_t} \right)^\alpha \int_0^1 L_{j,t} dj = Y_t \int_0^1 \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} dj$$

Given that aggregate labor demand equals aggregate labor supply $\int_0^1 L_{j,t} dj = L_t$, we have

$$\int_0^1 \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} dj Y_t = A_t \tilde{K}_t^\alpha L_t^{1-\alpha}$$

Thus, the aggregate production function can be written as

$$Y_t = \frac{A_t \tilde{K}_t^\alpha L_t^{1-\alpha}}{\Omega_t}$$

where $\Omega_t = \int_0^1 \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} dj$ measures a distortion introduced by the dispersion in relative prices.²³ In order to express Ω_t in aggregate terms, let decompose it according to the Calvo pricing assumption again, so that

$$\Omega_t = \int_0^1 \left(\frac{p_{j,t}}{p_t} \right)^{-\nu} dj = p_t^\nu \int_0^1 p_{j,t}^{-\nu}$$

$$p_t^\nu \int_0^1 p_{j,t}^{-\nu} = p_t^\nu \left(\int_0^{1-\zeta} p_t^{*\nu} dj + \int_{1-\zeta}^1 p_{j,t-1}^{-\nu} dj \right)$$

$$p_t^\nu \int_0^1 p_{j,t}^{-\nu} = p_t^\nu (1 - \zeta) p_t^{*\nu} + p_t^\nu \int_{1-\zeta}^1 p_{j,t-1}^{-\nu} dj$$

$$p_t^\nu \int_0^1 p_{j,t}^{-\nu} = (1 - \zeta) \left(\frac{p_t^*}{p_t} \right)^{-\nu} + p_t^\nu \int_{1-\zeta}^1 p_{j,t-1}^{-\nu} dj$$

$$p_t^\nu \int_0^1 p_{j,t}^{-\nu} = (1 - \zeta) \left(\frac{p_t^*}{p_{t-1}} \right)^{-\nu} \left(\frac{p_{t-1}}{p_t} \right)^{-\nu} + p_t^\nu \int_{1-\zeta}^1 p_{j,t-1}^{-\nu} dj$$

$$p_t^\nu \int_0^1 p_{j,t}^{-\nu} = (1 - \zeta)(1 + \pi_t^*)^{-\nu}(1 + \pi_t)^\nu + p_{t-1}^{-\nu} p_t^\nu \int_{1-\zeta}^1 \left(\frac{p_{j,t-1}}{p_{t-1}} \right)^{-\nu} dj$$

Given random sampling and the fact that there is a continuum of firms

$$\Omega_t = (1 - \zeta)(1 + \pi_t^*)^{-\nu}(1 + \pi_t)^\nu + \zeta(1 + \pi_t)^\nu \Omega_{t-1}$$

²³This distortion is not the one associated with the monopoly power of firms but an additional one that arises from the relative price fluctuations due to price stickiness.

A4. Full set of equilibrium conditions

$$K_{t+1} = \left\{ (1 - \delta u_t^\eta) K_t + \left[1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t \right\} (1 - \theta_t b_k) \quad (4.26)$$

$$\log \theta_t = (1 - \rho_\theta) \log \bar{\theta} + \rho_\theta \log \theta_{t-1} + \sigma_\theta \varepsilon_{\theta_t} \quad (4.27)$$

$$\tilde{K}_t = u_t K_t \quad (4.28)$$

$$\lambda_t = (C_t - hC_{t-1})^{-\gamma} - \beta h E_t (C_{t+1} - hC_t)^{-\gamma} \quad (4.29)$$

$$\chi L_t^\phi = w_t \lambda_t \quad (4.30)$$

$$\lambda_t = \beta E_t \lambda_{t+1} (1 + i_{t+1}) (1 + \pi_{t+1})^{-1} \quad (4.31)$$

$$\mu_t = \beta E_t [\lambda_{t+1} R_{t+1}^k u_{t+1} + \mu_{t+1} (1 - \delta u_{t+1}^\eta) (1 - \theta_{t+1} b_k)] \quad (4.32)$$

$$\lambda_t R_t^k = \mu_t \delta \eta u_t^{\eta-1} (1 - \theta_t b_k) \quad (4.33)$$

$$\begin{aligned} \lambda_t &= \mu_t (1 - \theta_t b_k) \left[1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \tau \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] \\ &\quad + \beta E_t \mu_{t+1} (1 - \theta_{t+1} b_k) \tau \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \end{aligned} \quad (4.34)$$

$$1 + i_t = (E_t Q_{t,t+1})^{-1} \quad (4.35)$$

$$q_t = \frac{\mu_t}{\lambda_t} \quad (4.36)$$

$$\log A_t = (1 - \rho_A) \log \bar{A} + \rho_A \log A_{t-1} + \sigma_A \varepsilon_{A_t} \quad (4.37)$$

$$w_t = mc^* (1 - \alpha) A_t \left(\frac{\tilde{K}_t}{L_t} \right)^\alpha \quad (4.38)$$

$$R_t^k = mc^* \alpha A_t \left(\frac{\tilde{K}_t}{L_t} \right)^{\alpha-1} \quad (4.39)$$

$$(1 + \pi_t^*) = (1 + \pi_t) \frac{\nu}{\nu - 1} E_t \frac{\tilde{\Xi}_{1_t}}{\tilde{\Xi}_{2_t}} \quad (4.40)$$

where $\tilde{\Xi}_{1_t} = \frac{\Xi_{1_t}}{p_t^\nu}$ and $\tilde{\Xi}_{2_t} = \frac{\Xi_{2_t}}{p_t^{\nu-1}}$.

$$\tilde{\Xi}_{1_t} = \lambda_t Y_t mc_t^* + \zeta \beta E_t \tilde{\Xi}_{1_{t+1}} (1 + \pi_{t+1})^\nu \quad (4.41)$$

$$\tilde{\Xi}_{2_t} = \lambda_t Y_t + \zeta \beta E_t \tilde{\Xi}_{2_{t+1}} (1 + \pi_{t+1})^{\nu-1} \quad (4.42)$$

$$i_t = \rho_i i_{t-1} + (1 - \rho_i) [\psi_\pi(\pi_t - \bar{\pi}) + \psi_Y(y_t - \bar{y}) + \bar{i}] + \sigma_i \varepsilon_{i_t} \quad (4.43)$$

$$\log G_t = (1 - \rho_G) \log(\omega \bar{Y}) + \rho_G \log G_{t-1} + \sigma_G \varepsilon_{G_t} \quad (4.44)$$

$$Y_t = C_t + I_t + G_t \quad (4.45)$$

$$Y_t = \frac{A_t \tilde{K}^\alpha L_t^{1-\alpha}}{\Omega_t} \quad (4.46)$$

$$(1 + \pi_t)^{1-\nu} = (1 - \zeta)(1 + \pi_t^*)^{1-\nu} + \zeta \quad (4.47)$$

$$\Omega_t = (1 - \zeta)(1 + \pi_t^*)^{-\nu}(1 + \pi_t)^\nu + \zeta(1 + \pi_t)^\nu \Omega_{t-1} \quad (4.48)$$

This is a system of 23 equations in 23 unknowns: $\{Y, C, I, G, A, L, K, \tilde{K}, u, w, R^k, \Omega, \pi, \pi^*, \tilde{\Xi}_1, \tilde{\Xi}_2, mc^*, \lambda, \mu, i, q, Q, \theta\}$.

A5. Steady State

From the FOC on investment (34), we have

$$\bar{\lambda} = \bar{\mu}(1 - \bar{\theta}b_k) \quad (4.49)$$

which implies by (36) that

$$\bar{q} = \frac{\bar{\mu}}{\bar{\lambda}} = \frac{1}{1 - \bar{\theta}b_k} \quad (4.50)$$

Without disaster risk, we would have $\bar{q} = 1$ determining the threshold under which firms invest or disinvest to raise their market value. Here disaster risk implies that this threshold is greater than unity since, for a given replacement cost in terms of utility, firms find it less profitable to invest as the probability that a part of their capital turns out to be destroyed rises.

Normalizing $\bar{u} = 1$, we have $\tilde{K} = \bar{K}$ from (28), and from (33)

$$\bar{R}^k = \delta\eta \quad (4.51)$$

Moreover (32) implies that

$$\bar{R}^k = \frac{1}{\beta(1 - \bar{\theta}b_k)} - (1 - \delta) \quad (4.52)$$

The last two equations imply a parameter restriction of η as

$$\eta = 1 + \frac{\frac{1}{\beta(1 - \bar{\theta}b_k)} - 1}{\delta} \quad (4.53)$$

Therefore, with parameter values $\beta = .99$, $\delta = .025$, $\bar{\theta} = .017$, and $b_k = .43$, we have $\eta = 1.7$ (and $\eta = 1.404$ in a world without disasters).

Then from (47), and given the target inflation rate $\bar{\pi}$, we have the steady-state reset inflation rate as

$$(1 + \bar{\pi}^*) = \left(\frac{(1 + \bar{\pi})^{1-\nu} - \zeta}{1 - \zeta} \right)^{\frac{1}{1-\nu}} \quad (4.54)$$

and, since from (40) we have,

$$(1 + \bar{\pi}^*) = (1 + \bar{\pi}) \frac{\nu}{\nu - 1} \frac{\tilde{\Xi}_1}{\tilde{\Xi}_1} \quad (4.55)$$

where, from (41) and (42),

$$\tilde{\Xi}_1 = \frac{\bar{\lambda} \bar{Y} \bar{m} c^*}{1 - \zeta \beta (1 + \bar{\pi})^\nu} \quad (4.56)$$

$$\tilde{\Xi}_2 = \frac{\bar{\lambda} \bar{Y}}{1 - \zeta \beta (1 + \bar{\pi})^{\nu-1}} \quad (4.57)$$

we get

$$(1 + \bar{\pi}^*) = (1 + \bar{\pi}) \frac{\nu}{\nu - 1} \bar{m} c^* \frac{1 - \zeta \beta (1 + \bar{\pi})^{\nu-1}}{1 - \zeta \beta (1 + \bar{\pi})^\nu} \quad (4.58)$$

which gives the steady-state marginal cost $\bar{m}c^*$ as

$$\bar{m}c^* = \frac{\nu - 1}{\nu} \frac{1}{(1 + \bar{\pi})} \frac{1 - \zeta\beta(1 + \bar{\pi})^\nu}{1 - \zeta\beta(1 + \bar{\pi})^{\nu-1}} \left(\frac{(1 + \bar{\pi})^{1-\nu} - \zeta}{1 - \zeta} \right)^{\frac{1}{1-\nu}} \quad (4.59)$$

Note that we must therefore restrict parameter values so that $\zeta\beta(1 + \bar{\pi})^\nu < 1$.

With the expressions for \bar{R}^k and $\bar{m}c^*$, we can express the steady-state capital-labor ratio as a function of the steady-state characteristics of disaster from (39)

$$\frac{\bar{K}}{\bar{L}} = \left(\frac{\bar{m}c^* \alpha \bar{a}}{\bar{R}^k} \right)^{\frac{1}{1-\alpha}} \quad (4.60)$$

Therefore the steady-state wage is given by (38)

$$\bar{w} = \bar{m}c^*(1 - \alpha)\bar{a} \left(\frac{\bar{K}}{\bar{L}} \right)^\alpha \quad (4.61)$$

From (48), we have

$$\bar{\Omega} = \frac{(1 - \zeta)(1 + \bar{\pi}^*)^{-\nu}(1 + \bar{\pi})^\nu}{1 - \zeta(1 + \bar{\pi})^\nu} \quad (4.62)$$

From the law of capital accumulation (26) in steady-state, we have

$$\bar{I} = \bar{K} \left(\frac{1}{1 - \theta b_k} - (1 - \delta) \right) \quad (4.63)$$

and given that from (44),

$$\bar{G} = \omega \bar{Y} \quad (4.64)$$

the accounting identity (45) becomes in steady-state

$$\bar{Y} = \frac{1}{1 - \omega} \left\{ \bar{C} + \bar{K} \left[\frac{1}{1 - \theta b_k} - (1 - \delta) \right] \right\} \quad (4.65)$$

in which $\frac{1}{1-\omega}$ is the keynesian multiplier of public expenditures. Fur-

ther dividing each side by \bar{L} gives

$$\frac{\bar{Y}}{\bar{L}} = \frac{1}{1-\omega} \left\{ \frac{\bar{C}}{\bar{L}} + \frac{\bar{K}}{\bar{L}} \left[\frac{1}{1-\bar{\theta}b_k} - (1-\delta) \right] \right\} \quad (4.66)$$

Replacing the left-hand side by the output-labor ratio obtained from the aggregate production function (46), we have

$$\frac{\bar{A}}{\bar{\Omega}} \left(\frac{\bar{K}}{\bar{L}} \right)^\alpha = \frac{1}{1-\omega} \left\{ \frac{\bar{C}}{\bar{L}} + \frac{\bar{K}}{\bar{L}} \left[\frac{1}{1-\bar{\theta}b_k} - (1-\delta) \right] \right\} \quad (4.67)$$

which can be solved for the steady-state consumption-labor ratio as

$$\frac{\bar{C}}{\bar{L}} = \frac{\bar{A}(1-\omega)}{\bar{\Omega}} \left(\frac{\bar{K}}{\bar{L}} \right)^\alpha - \frac{\bar{K}}{\bar{L}} \left[\frac{1}{1-\bar{\theta}b_k} - (1-\delta) \right] \quad (4.68)$$

Combining the FOC on consumption (29) in steady-state

$$\bar{\lambda} = [(1-h)\bar{C}]^{-\gamma} (1-\beta h) \quad (4.69)$$

with the FOC on labor (30) in steady-state

$$\bar{L} = \left(\frac{\bar{w}\bar{\lambda}}{\chi} \right)^{1/\phi} \quad (4.70)$$

we can express \bar{L} as a function of the steady state consumption-labor ratio

$$\bar{L} = \left[\frac{\bar{w}(1-h)^{-\gamma} \left(\frac{\bar{C}}{\bar{L}} \right)^{-\gamma} (1-\beta h)}{\chi_L} \right]^{\frac{1}{\phi_L+\gamma}} \quad (4.71)$$

which gives $\bar{\lambda}$ by (69) and therefore $\bar{\mu}$. \bar{L} also gives \bar{Y} by (66) and \bar{K} by (60). Then \bar{G} is obtained by (64) and \bar{I} by the accounting identity or by (63). Then we get $\tilde{\Xi}_1$ and $\tilde{\Xi}_2$ by (56) and (57).

Finally, from the FOC on bonds (31) we have the standard Fisher relation between the subjective discount factor, the nominal interest rate and the inflation rate, $1/\beta = (1+\bar{i})/(1+\bar{\pi})$, such that, by (35),

the one-period stochastic discount factor is

$$\bar{Q} = \frac{1}{1 + \bar{i}} = \frac{\beta}{1 + \bar{\pi}} \quad (4.72)$$

A6. Tables**Table 4.1:** Baseline calibration parameters (quarterly values)

Utility function		
β	discount factor	0.99
γ	inverse of EIS / risk aversion coefficient	2
h	habit in consumption	0.7
ϕ	inverse of the elasticity of work effort to the real wage	1
χ	labor disutility weight	4.74
Investment		
δ	capital depreciation rate	0.025
τ	investment adjustment costs	0.5
\bar{u}	utilization rate of capital	1
Production		
α	capital share of production	0.33
ζ_0	Calvo probability	0.8
ν	elasticity of substitution among intermediate goods	6
Public authority		
ω	steady-state G/Y ratio	0.2
ψ_π	Taylor rule inflation weight	1.5
ψ_Y	Taylor rule output weight	0.5
$\bar{\pi}$	target inflation rate	0.005
ρ_A	TFP smoothing parameter	0.9
ρ_G	government expenditures smoothing parameter	0.85
ρ_i	interest rate smoothing parameter	0.85
Disaster risk		
$\bar{\theta}$	disaster risk	0.01
b_k	share of capital destroyed if disaster	0.43
ρ_θ	disaster risk smoothing parameter	0.85
σ	standard deviation of shocks	0.01

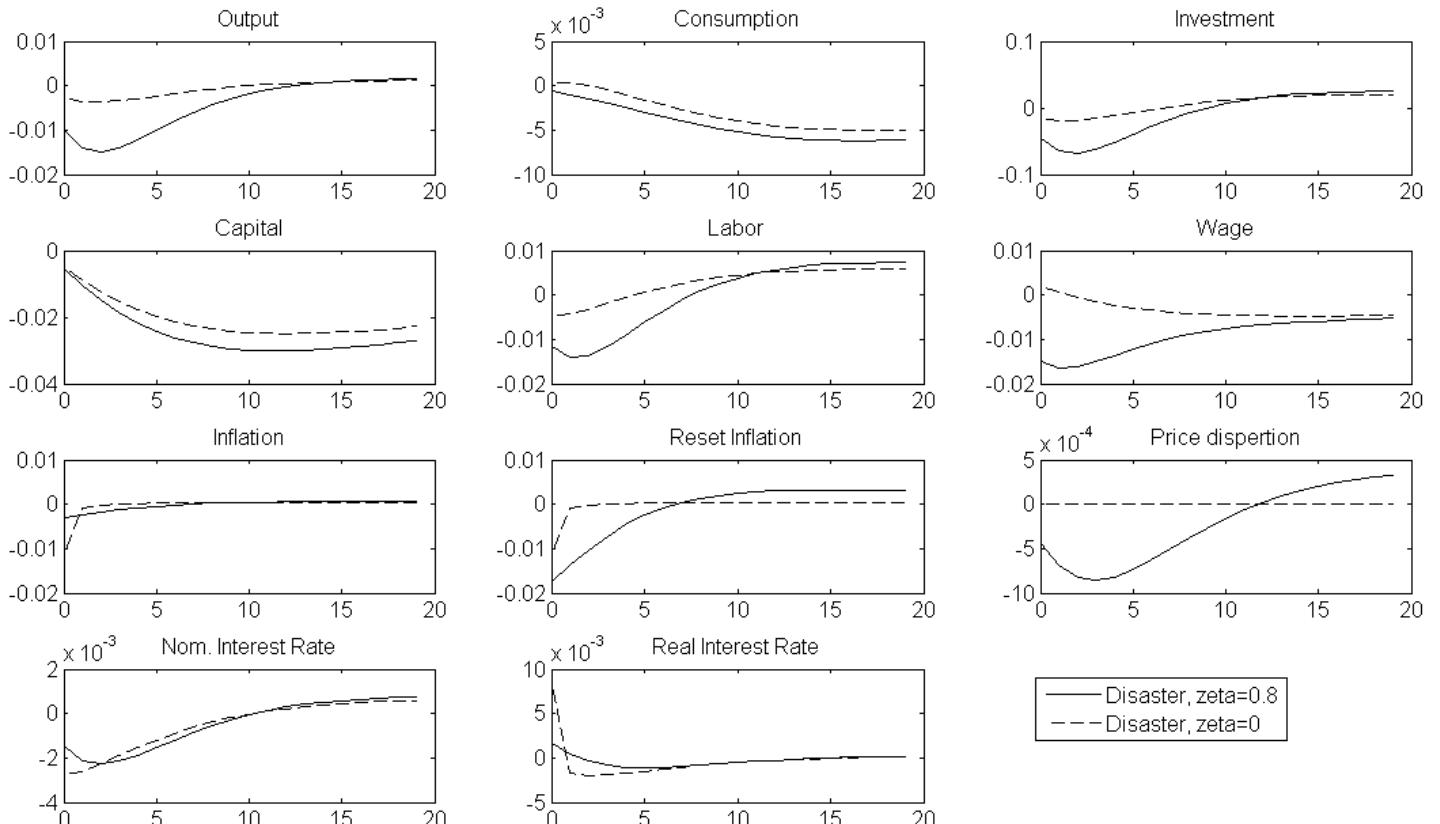


Figure 4.1: Standard-deviation responses to a shock to the probability of disaster (increase in θ).

Solid line: model with disaster risk and sticky prices ($\zeta = 0.8$). Dashed line: model with disaster risk and flexible prices ($\zeta = 0$).

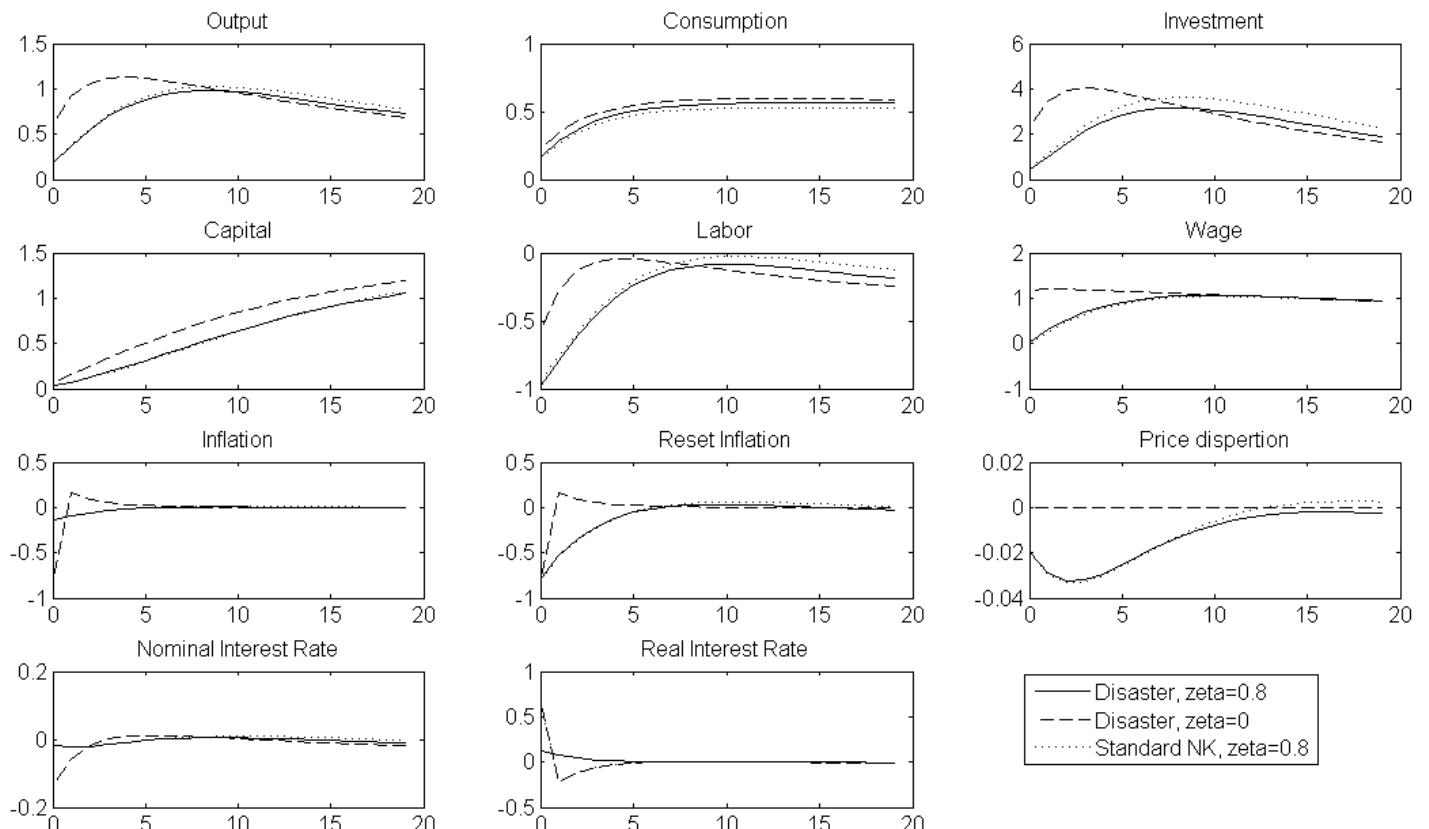


Figure 4.2: Standard-deviation responses to a productivity shock. Solid line: model with disaster risk and sticky prices ($\zeta = 0.8$). Dashed line: model with disaster risk and flexible prices ($\zeta = 0$). Dotted line: model without disasters, with sticky prices.

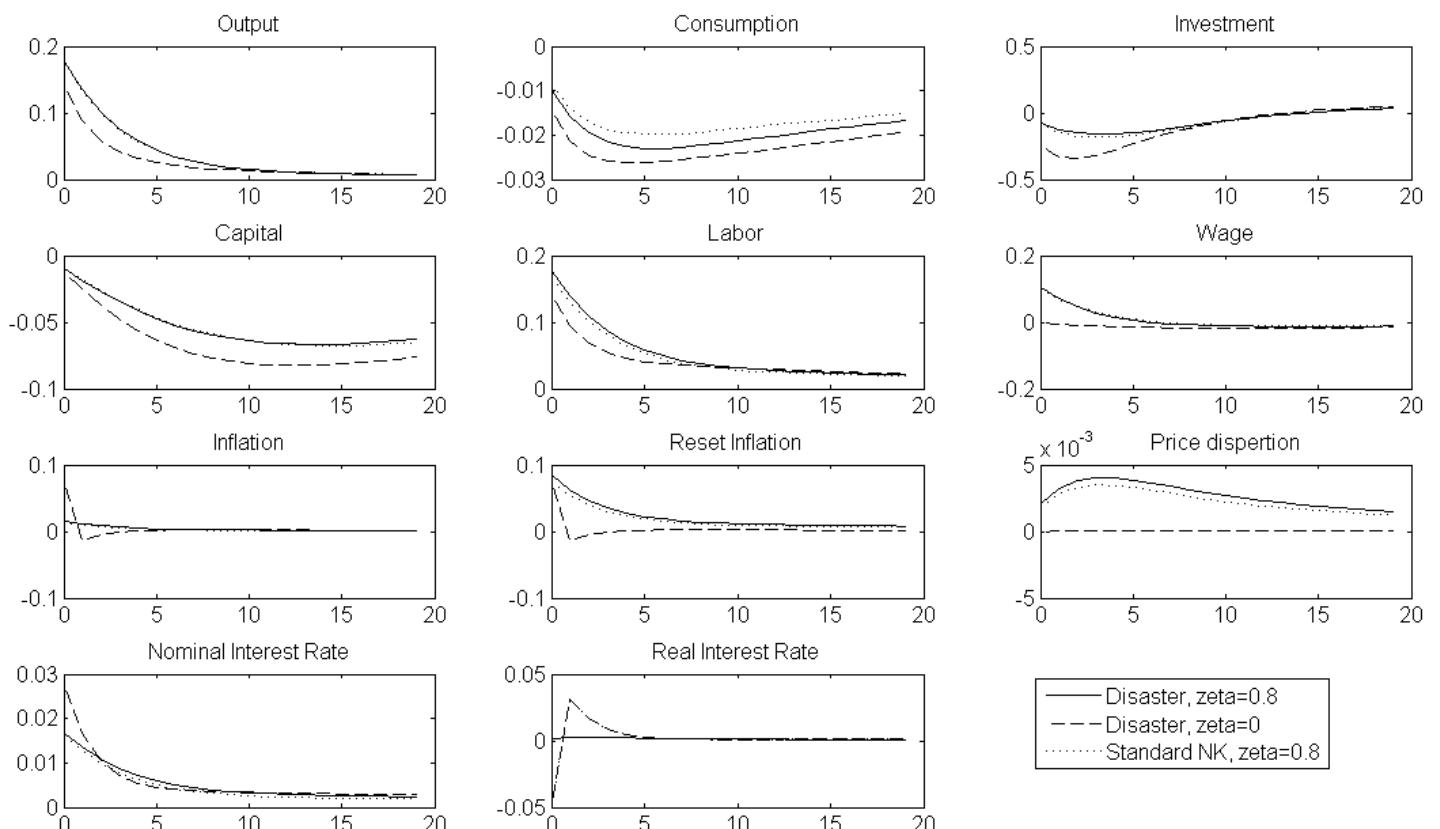


Figure 4.3: Standard-deviation responses to a public spending shock. Solid line: model with disaster risk and sticky prices ($\zeta = 0.8$). Dashed line: model with disaster risk and flexible prices ($\zeta = 0$). Dotted line: model without disasters, with sticky prices.

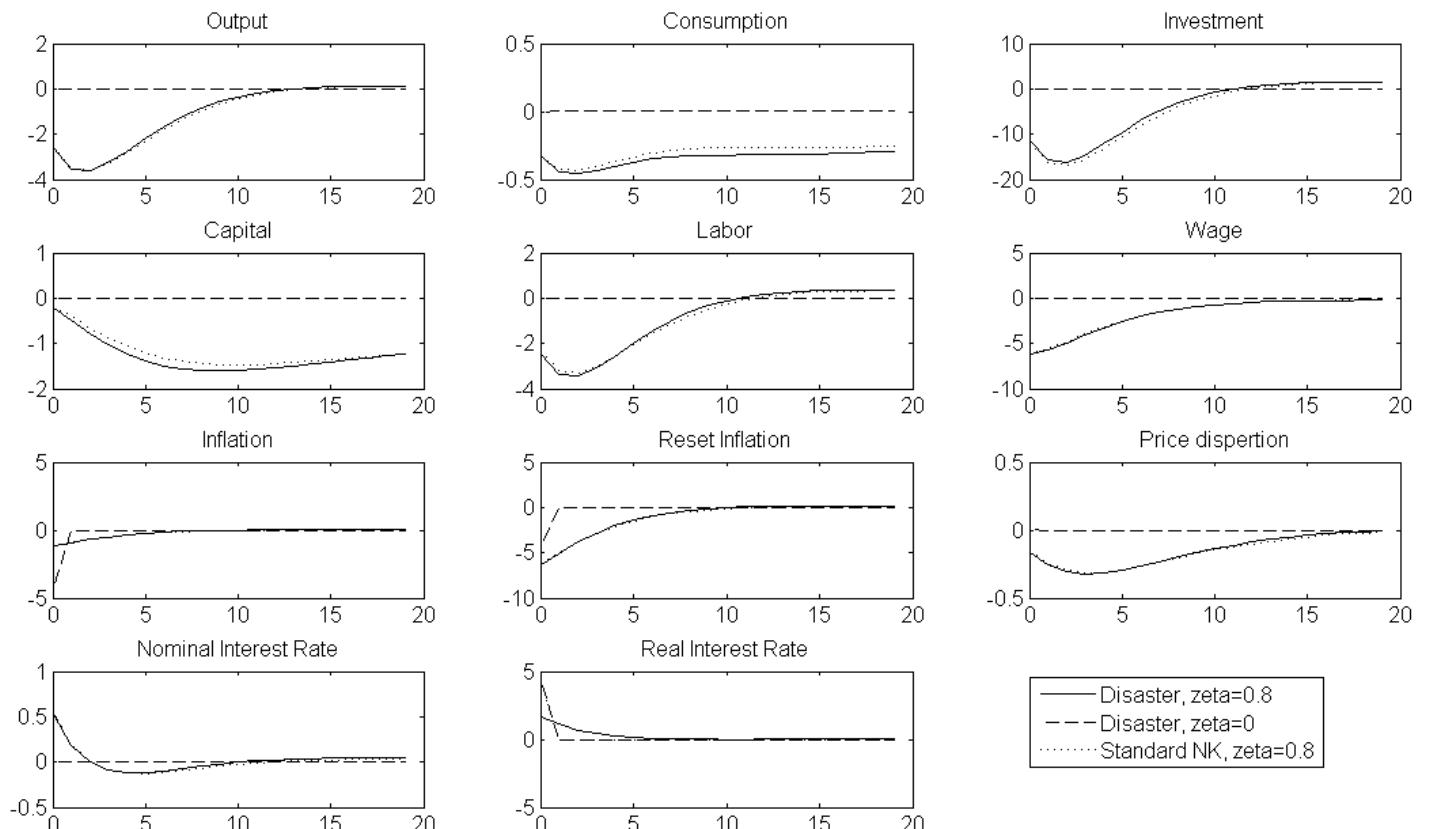


Figure 4.4: Standard-deviation responses to a monetary shock. Solid line: model with disaster risk and sticky prices ($\zeta = 0.8$). Dashed line: model with disaster risk and flexible prices ($\zeta = 0$). Dotted line: model without disasters, with sticky prices.

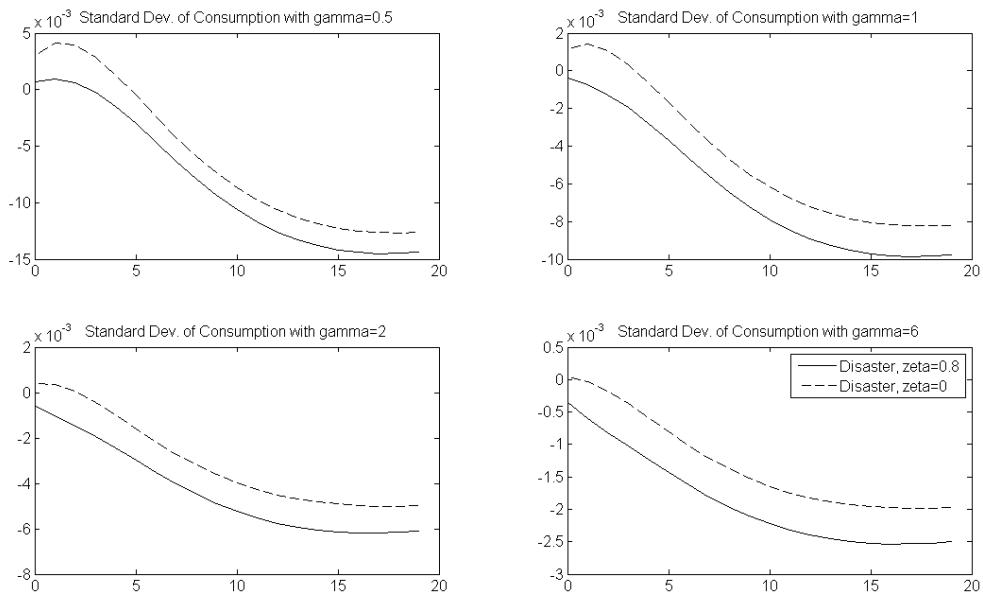


Figure 4.5: Standard-deviation of consumption to a shock to the probability of disaster, for different values of the risk aversion coefficient γ .

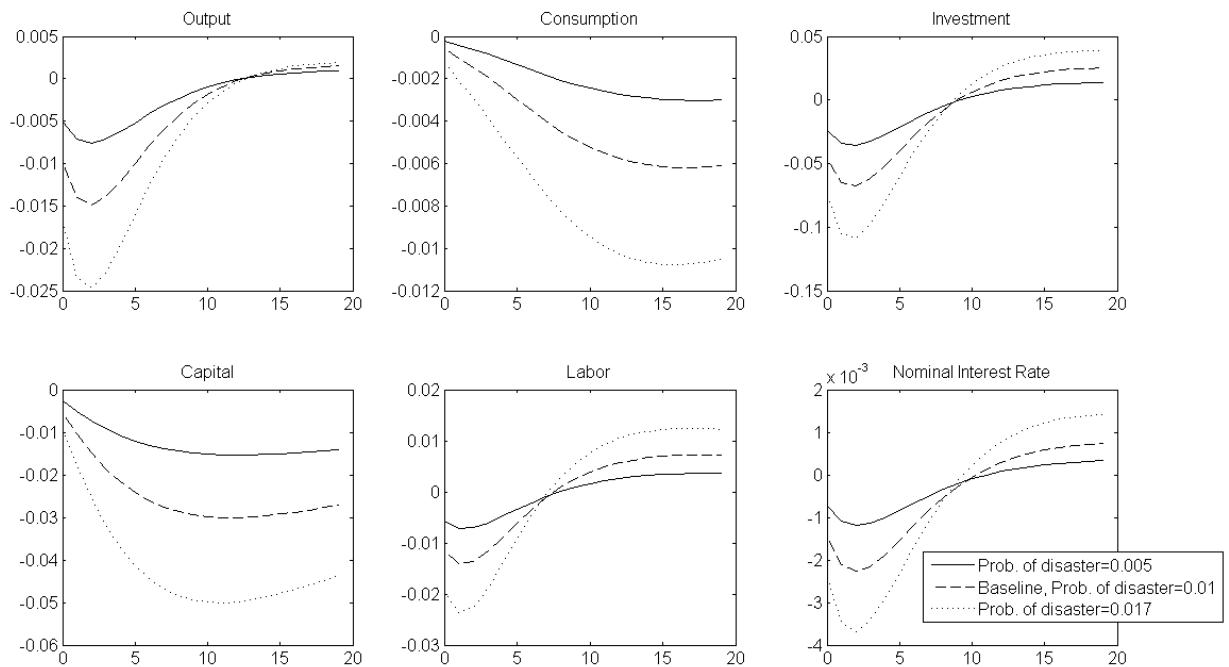


Figure 4.6: Standard-deviation responses to a shock to the probability of disaster, for different values of the steady-state probability of disaster, $\bar{\theta}$.

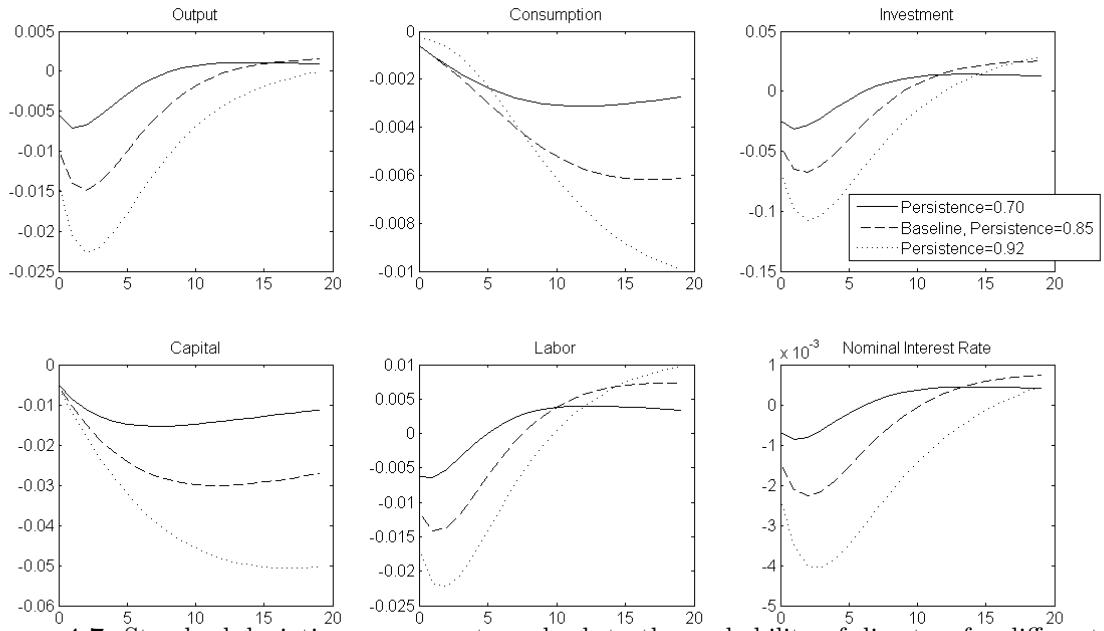


Figure 4.7: Standard-deviation responses to a shock to the probability of disaster, for different values of the persistence of the shock ρ_θ .

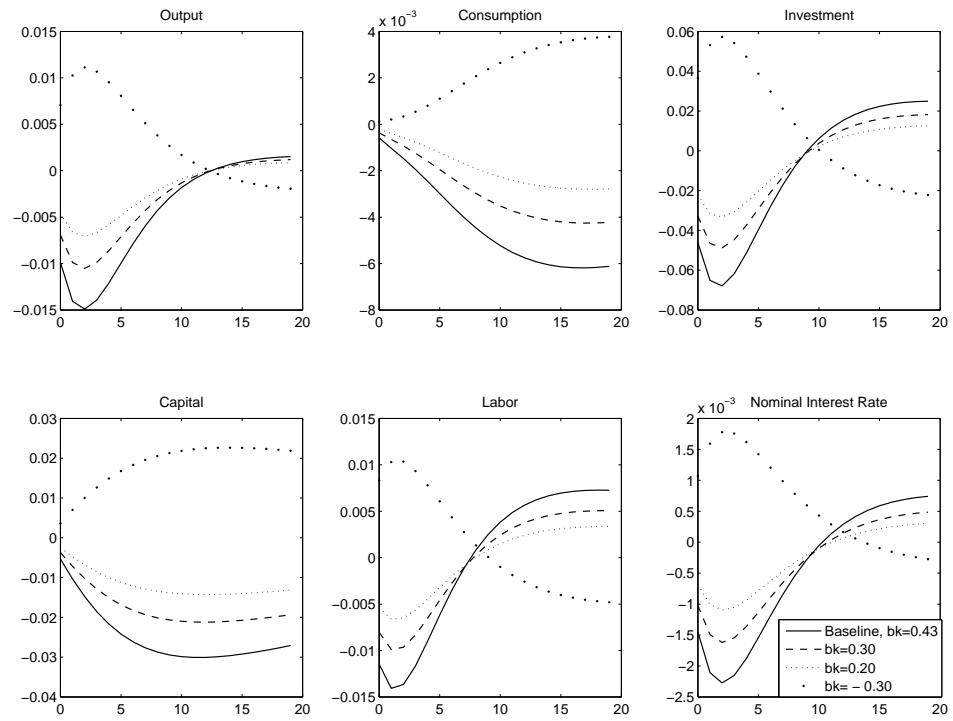


Figure 4.8: Standard-deviation responses to a shock to the probability of disaster, for different values of the destroyed share of capital b_k .

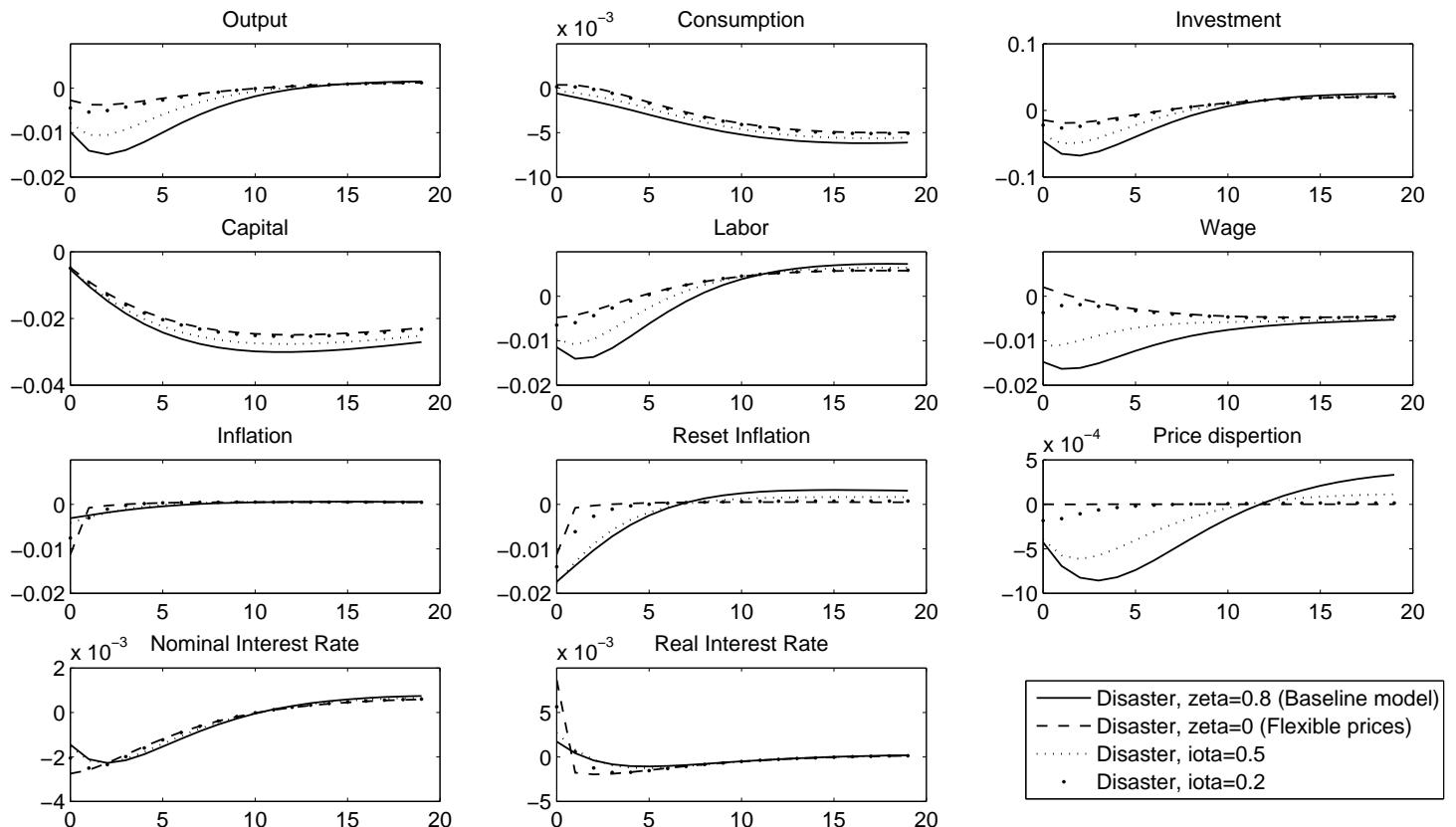


Figure 4.9: Standard-deviation responses to a shock to the probability of disaster, with state-dependent price stickiness. We assume that $\zeta_t = \zeta_0 - \theta_t^\nu$. With $\nu \geq 1$, the responses are very close to the Calvo pricing case ($\zeta = 0.8$), thus not included.

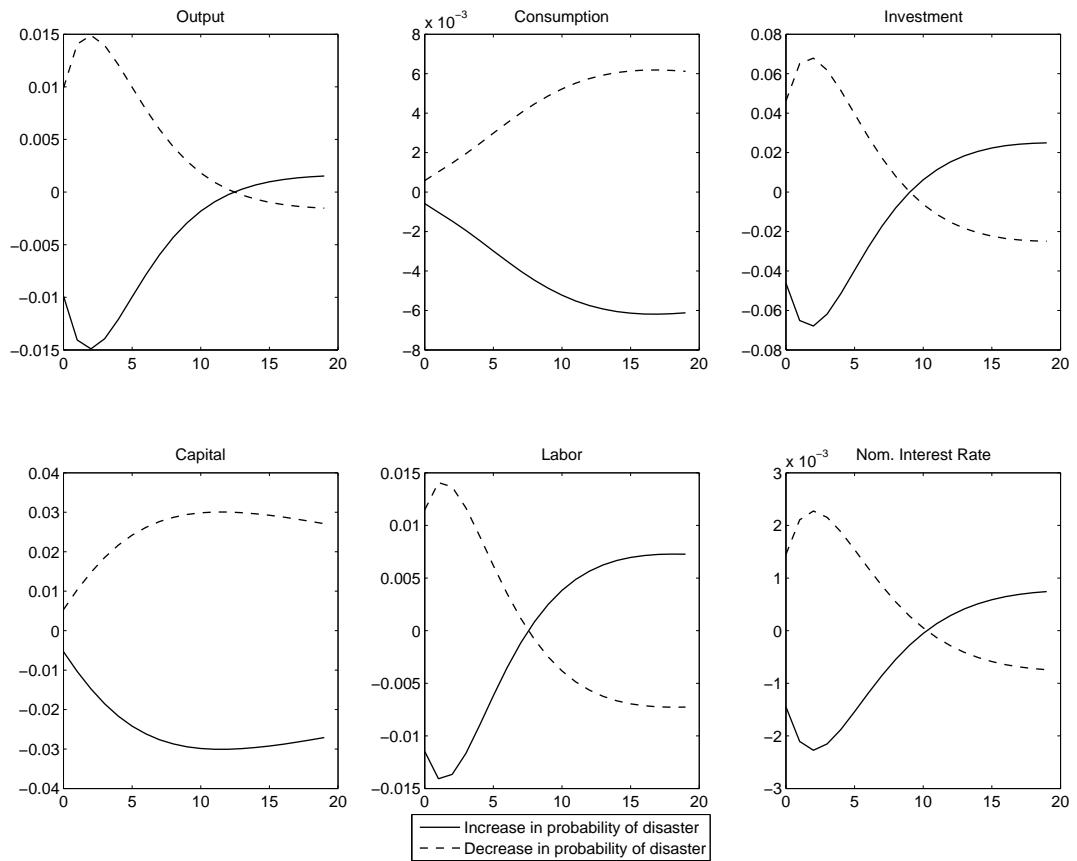


Figure 4.10: Standard-deviation responses to a shock to the probability of disaster. Negative and positive shocks.

Table 4.2: Correction terms for the second-order approximation, shock to θ

	\hat{Y}	\hat{C}	\hat{I}	\hat{G}	\hat{K}	\hat{L}	$\hat{\Omega}$
Constant	0.691892	0.169961	-0.884952	-0.917545	2.644587	-0.281788	0.001777
2nd-order correction	-0.000001	0	-0.000004	0	0	0	0
	$\hat{\pi}$	$\hat{\pi}^*$	$\hat{m}c^*$	\hat{w}	\hat{R}^k	\hat{q}	\hat{Q}
Constant	0.004987	0.026281	-0.182864	0.387128	-3.232391	0.004307	-0.015038
2nd-order correction	0	-0.000003	-0.000006	-0.000007	-0.000004	-0.000002	0

General Conclusion

Unconventional monetary policies have become important part of central bank strategy to deal with increased uncertainty and risk premia in financial markets. Yet, the theoretical and empirical evidence does not allow drawing definite conclusions about the desirability and effectiveness of non-orthodox measures. This thesis contributes to better understanding of unconventional monetary policies from conceptual, empirical and theoretical point of view.

In the first chapter, we discussed the different ways of implementing unconventional monetary policies in Japan (1999-2001) and the United States (2007-2010) with a particular focus on central-bank balance sheet management. We showed that the Fed purchased risky assets much more intensively than the BOJ did putting much more emphasis on the credit-easing transmission channels. The BOJ on the other hand focused on providing excess reserves to commercial banks without getting too much risky assets on its balance sheet getting closer to pure quantitative easing. The Fed's "asset-driven" balance sheet management required large increase in banks' excess reserves and the Fed encouraged banks to keep the reserves idle by paying interest rates on them. On the contrary, the BOJ intended banks to use the excess reserves to distribute credit to economy. The analysis of the U.S. and Japanese commercial banks balance sheets shows that country-specific characteristics mattered for the design and effectiveness of unconventional policies. The U.S. crisis was principally due to bad-security issue and the Fed had to purchase the assets that private agents did not want to hold. The aggregate lending diminished to smaller extent than in Japan. The disruption of interbank market was much stronger which might be linked to interest bearing excess reserves. Japan on the other hand had to deal with bad-loan problem and the extensive liquidity provisions were intended to encourage banks to lend. The double deleveraging of banks and firms made this strategy unsuccess-

ful and aggregate lending diminished much more than in the U.S. Finally, the empirical evidence for two countries confirms the difference in the strategy of the the Fed and the BOJ: while the Fed government bond purchases had significant impact on the U.S. long-term interest rates, the BOJ purchases did not reduce Japanese rates.

The second and third chapter evaluated empirically the effectiveness of different kinds of unconventional monetary policies. Chapter 2 focused on non-orthodox measures implemented by the Fed and in particular on their impact on Libor-OIS spread, long-term interest rates and long-term inflation expectations. We employed event-based regression in order to measure the relevant assets responses to unconventional monetary policy announcements. First, we found that interbank market reacts relatively little to unconventional monetary policy news. This confirms the conclusion of the first chapter on the substitution of the Fed for interbank market and smaller importance of this market for bank refinancing. This result also supports the hypothesis that credit risk linked to interbank lending was of much greater importance than liquidity risk and the Fed's liquidity facilities (TAF in particular) were unable to reduce it. Second, we provide evidence on different impact of quantitative easing 1 (QE1) and quantitative easing 2 (QE2) in the U.S. The first government bonds purchasing program diminished long-term interest rates and did not impact long-term inflation expectations. The second program increased long-term inflation expectations but did not reduce long-term interest rates. This reaction of inflation expectation can be explained if one supposes that economic agents perceived QE2 as an indication that the Fed intends monetary expansion to be permanent. According to Auerbach and Obstfeld (2005)'s model only permanent quantitative easing can increase inflation. Moreover, the independence of the Fed with respect to Treasury might be more of an issue as the government bond purchases continued along with fiscal stimulus. The inflationary impact of rescue operations, often conducted with Treasury, seems to confirm the agents' sensibility to that question.

Chapter 3 assessed the impact of the ECB unconventional monetary policies on market borrowing costs for governments and banks. We took into account all non-orthodox ECB measures, including the latest sovereign bonds purchasing program (Outright Monetary Transac-

tions, OMT), and used event-based regression to measure the impact of each measure. We considered money market and covered bonds market spreads as a proxy for the banks' borrowing conditions and sovereign bonds spreads as a proxy for the euro-zone governments' borrowing rates. The results of this chapter confirm the earlier conclusions on the Fed's liquidity measures. The exceptional liquidity facilities did not affect interbank money spreads significantly. The important exception however is three-year longer-term refinancing operation (3Y LTRO) which contributed to significant reduction of the spreads. Covered bonds purchasing programs (CBPP 1 and 2) also diminished the money market spreads to some extent. Furthermore, we show that longer-term banks' refinancing source - the covered bonds market - reacted much more to the ECB unconventional measures. The long-term sovereign bond purchasing program (SMP) had the biggest impact as its reduced the country default probability and therefore improved the business climate. Covered bonds purchases, short-term sovereign debt purchasing program (OMT) and 3Y LTRO also lowered the covered bonds spreads. Finally, we find that the sovereign bonds spreads in periphery euro-zone countries reacted strongly to both SPM and OMT, as these programs were supposed to counter the "bad-equilibrium" outcome, namely default of a member state or its exit from the euro-zone.

These empirical results provide some positive evidence on the effectiveness of unconventional monetary policies on market interest rates and in particular on longer-term interest rates. However, as discussed in Chapter 1 and 2, the ultimate objective of unconventional policies was increase in lending to companies and households and these measures were not accompanied by rise in higher monetary aggregates. Moreover, the Fed encouraged banks to keep excess reserves on its balance sheet by paying interest on them. The impact of non-orthodox measures on bank lending in terms of interest rates and quantities, seems therefore an important avenue of further research. A parallel question linked to unconventional monetary policies is a welfare distribution they entail. Central banks provided cheap and almost unlimited liquidity to financial institutions and the maturity of loans reached 3 years. It is important to measure whether these funds were used for credit distribution or invested in short-term government debt bringing

“carry-trade”-like profits. In a similar vein, the recent Fed’s mortgage-backed securities buying program, called QE3, is reported to increase the profits of few mortgage-originating financial institutions which do not pass on low interest rates to households²⁴. Again, the pass-through of lower interest rates induced by unconventional policies to lending rates to companies and households would be a key element to evaluate overall effectiveness of these measures.

As far as theoretical results are concerned, we developed in chapter 4 a New Keynesian model that incorporates a small time-varying risk of disaster. This paper is a first step towards the introduction of rare events risk into the models used to conduct monetary policy, and will be used to compare the effectiveness of several unconventional monetary policy interventions in the presence of such a risk. In the first stage we developed a baseline framework to analyze macroeconomic quantities in the presence of a small time-varying disaster risk in an otherwise standard New Keynesian model. A rise in the probability of disaster creates a recession, a fall in inflation, a flight to quality in terms of asset demand, depressed investment and labor, as well as lower consumption. The rise in a probability of a disaster suffices to generate this recession, without effective occurrence of the disaster. While following Gourio (2012) on the description of an economic disaster, we relax the assumption that total factor productivity needs to fall by the same amount than the capital stock in case of a disaster. By incorporating investment adjustment costs and monopolistic competition, we show that the magnitude of the recession following a shock to the probability of disaster may be far increased. As compared with the early papers on rare events, we also account for the fact that consumption and wages do not rise in distressed economic times, whether nominal rigidity is time-dependent or state-dependent. As a second step, we plan to assess the desirability of monetary policy to prevent a (self-fulfilling) recession from a sudden rise in the (perceived) probability of disaster. Several conventional and unconventional interventions will be compared with one another by incorporating a welfare function measuring their effectiveness.

This thesis emphasized the diversity of unconventional monetary policy strategies and the importance of country-specific characteristics for

²⁴“Fears over US mortgage dominance”, Financial Times, October 15, 2012.

their design and effectiveness. We conclude that direct asset purchases have important effect on long-term interest rates reduction, especially in the presence of high country default risk. The government bond purchases seem to have an impact on inflation expectations as long as the monetary base is perceived to be permanent. The impact of quantitative easing on inflation expectations should be however investigated further taking into account the U.K., the euro-zone data, as well as the newest evidence from the United States (QE3 and Operation Twist) in order to determine more precisely the conditions which allow large-scale asset purchases to have an impact on inflation expectations. We also find that liquidity provisions had only small impact on interbank market strains. We conclude that the central banks took the role of interbank intermediation making interbank market less relevant for the bank refinancing. The future research is needed in order to determine whether liquidity provided to banks was further lent to companies and households and whether the low interest rates were further passed on to banks' customers. Finally, we built a New Keynesian model that accounts for agents' perception of higher disaster risk which leads to self-fulfilling recession. This is a privileged framework to evaluate efficacy of unconventional monetary policies and we plan to compare different unconventional measures in term of welfare gains (losses) in our further research.

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