A Lesson from the Great Depression that the Fed Might have Learned: A Comparison of the 1932 Open Market Purchases with Quantitative Easing

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Abstract

We examine the first QE program through the lens of an open-market operation undertaken by the Federal Reserve in 1932, at the height of the Great Depression. This program entailed large purchases of medium- and long-term securities over a four-month period. There were no prior announcements about the size or composition of the operation, how long it would be put in place, and the program ended abruptly. Using a dataset with weekly-level Treasury holdings of the Federal Reserve in 1932, and the corresponding yields, we first conduct an event study analysis. This indicates that the 1932 program significantly lowered medium- and long-term Treasury yields. We then use a segmented markets model to analyze the channel through which the open-market purchases affected the economy. Quarterly data from 1920-32 is used to estimate the model with Bayesian methods, employing the methodology of Chen, Cúrdia and Ferrero (2012). We find that the significant degree of financial market segmentation in this period made the historical open market purchase operation more effective than QE in stimulating output growth. Additionally, if the Federal Reserve had continued its operations in 1932, and used the announcement strategy of the QE operation, the upturn in economic activity during the Great Depression could have been achieved sooner.

JEL Classifications: E43, E44, E58

1 Introduction

During the recovery period following the financial crisis of 2007-09, there has been considerable debate about the effectiveness of the Quantitative Easing (QE) programs of the Federal Reserve, and their significance for the economic recovery. The primary mechanism used to examine the impact of the QE programs has been to estimate the effect of the programs on the term structure of different types of yields, and an expanding literature has examined the effect on Treasury yields[3]. In these analyses, there are two main challenges in analyzing the effects of the QE programs: first, the decline in the state of the economy during the crisis period was unprecedented, and the effects of the monetary policy intervention were complicated by the freezing up of credit markets; and second, there were several unconventional monetary policy tools deployed in the QE program: forward guidance which provided guidelines about the size and length of the programs, the presence of the zero-lower bound and the payment of interest rate on excess reserves.

In our analysis, we provide a new perspective on examining the effects of the QE programs, by comparing the size and effectiveness of the program to another policy initiative of the Federal Reserve during the Great Depression of 1929 to 1933. After three years of severe recession, in the face of Congressional pressure, the Federal Reserve undertook a significant open market operation between April and August 1932, in which it bought a billion dollars of medium and long term securities ($16 billion in today's prices or 2% of 1932 GNP). The New York Times noted, "By entering upon a policy of controlled credit expansion, designed to turn the deflation in bank credit and to stimulate a rise in prices, the Federal Reserve System has undertaken the boldest of all central bank efforts to combat the depression."[4]

[3] Swanson (2011), Krishnamurthy and Vissing-Jorgensen (2011).

[4] The *New York Times*, quoted in the *Commerical and Financial Chronicle*, April 16, 1932, p. 2774.

Although the purchase program was motivated by the economic and political conditions of a very different era, the program had important effects on the term structure of Treasury yields. The size of the intervention was comparable to the first QE program, conducted by the Federal Reserve between November 2008 and March 2009. The states of the economy during the 1932 operation, and the first QE program were very similar in terms of key macroeconomic and financial terms. At the time of both operations, the Congress and the public were desperate for active intervention by the central bank. Therefore, we propose to use the 1932 operation as a natural experiment to examine the effectiveness of the QE program, and the importance of using tools such as forward guidance. In this analysis, we will only consider the first QE program, as the successive programs were anticipated to some degree by financial market participants.

While the environment in which these programs were conducted was similar, there were also some important differences. In 1932, there was no announcement by the Federal Reserve of its intention to conduct these open-market operations, nor any indication of how long they would last or what the size would be. There were other differences as well: the portfolio of the Federal Reserve in 1932 contained a larger proportion of medium-term Treasury notes relative to bonds in 1932, and it did not pay an interest rate on excess reserves. Finally, unlike the QE period, the 1932 operation was a pure open-market operation, i.e., it did not buy any other types of assets. We discuss the implications of these differences in detail below.

Despite these differences, we find that although the 1932 operation was significantly shorter in duration (and the balance sheet of the Federal Reserve was much smaller), the program had large impact effects on the economy. We first analyze the effect of the operation on the cross section of Treasury yields using an event study methodology. We find that the

notes and bond yields changed significantly over this period: for instance, following the first set of Treasury notes purchases by the Federal Reserve, the yields on 3-5 year notes declined by 36 b.p. in the week of April 27, 1932.

We then use quarterly data from 1920-32 to estimate the effects of the open-market operation in a general equilibrium model with segmented markets. There was a significant degree of market segmentation in the 1930s as the non bank public had limited access to the government securities markets which was dominated by a few investment banks (Garbade, 2012). As reported by Banking and Monetary Statistics (1914-1941), discount rates of different Federal Reserve districts varied for the same time period, providing further evidence of market segmentation. The disparity was as much as between 50 and 150 basis points (for example, in December 1930, the discount rate reported in New York was 2%, and San Francisco it was 3.5%).[5] The difference in rates was also evident in other types of loans. For instance, in December 1930, the rate charged on commercial loans by banks was 3.82% in New York, 4.38% in seven other Northeastern cities and 5.01% in eleven Southern and Western cities.[6]

The main hypothesis of the model is that there were two types of financial market participants: the first type of investors could hold both long- and short-term Treasury securities, and the second could only hold long-term assets. However, the former type of agents paid a transaction cost for buying long-term assets. Private domestic households had limited access to long-term bonds during the 1920s and 1930s, and therefore, we find this to be a plausible way to model their holdings of Treasury securities. Using data to estimate the degree of segmentation, we find that it was much higher for 1920-32 than for 2008-2009; thus, agents were not able to substitute between the different types of Treasury securities (as they would

[5] Banking and Monetary Statistics of the Federal Reserve, 1914-1941, Table 115, pp. 441.
[6] Banking and Monetary Statistics of the Federal Reserve, 1914-1941, Table 125, pp. 464.

have without any frictions). The purchases of long-term securities by the central bank in this model then affects the long-term yield, and consequently, the savings and consumption decisions of households. The high segmentation explains why the open market operation in 1932 was effective in lowering Treasury yields and boosting output growth, even though it lasted less than two quarters. Our results suggest that since segmentation is substantially lower in modern financial markets, agents are better able to balance their portfolios better, and therefore, the Federal Reserve had to utilize unconventional tools of monetary policy such as forward guidance in order to affect the real economy during the 2008 crisis. We further find that had the announcement strategy of the QE program been used in 1932, the effects on the real economy would be magnified.

The paper is organized as follows: section 2 contextualizes our analysis in the literature, and the QE and 1932 operations are discussed in section 3. Section 4 analyzes the main channels through which asset purchase programs will affect the economy, and the event study methodology is discussed in section 5. Section 6 presents the model and the results, and section 7 concludes.

2 Context in the Literature

The first part of this paper analyzes the 1932 and QE1 operations using an event study methodology. The strategy is similar to the analyses of Krishnamurthy and Vissing-Jorgensen (2011) and Swanson (2011) for the QE1 period: we estimate the changes in Treasury yields around announcements by the Federal Reserve. In case of the 1932 operation, since no public announcements were made, we first identify weeks in which there were significant changes in the Federal Reserve's holdings of Treasury securities, and then analyze the changes in yields

during these periods. This is similar to the strategy followed by Landon-Lane (2013). The results of the event study methodology suggest that the 1932 operation had a significant effect on yields.

Several papers explore the consequences of the 1932 open market operation for the economy. Meltzer (2003) discusses the economic and political context of the operation. Hsieh and Romer (2006) examine the effects of the operation on expectations of devaluation, and whether the Fed could have continued the operation without a loss of credibility and commitment to the gold standard. Bordo, Choudhari and Schwartz (2003) argue that since the United States was a large open economy in 1932, and has vast gold reserves, the expansionary open market operations would not have caused an outflow of gold, even under the extreme assumption of perfect capital mobility.

The second part of our analysis focuses on exploring the channel through which the purchase programs affected real variables in the economy. Since segmentation was a common feature of financial markets in the 1920s and 1930s, to model the effects of the asset purchase programs on the economy, we use a segmented markets framework. This is based on the models of Andrés, López-Salido and Nelson (2004) and Chen, Cúrdia and Ferrero (2012). The approach of using segmented markets as a channel for analyzing the effects of open-market operations have been widely used. Occhino (2004) uses a model in which households are permanently excluded from the market in government securities, and is able to replicate the persistent decrease in money growth and increase in real interest rates following an unexpected increase in the nominal interest rate. Alvarez, Atkeson and Kehoe (2002) introduce endogenous market segmentation by introducing a fixed cost which agents must pay to exchange bonds and money. In our approach, one type of investor is excluded from holding short-term bonds, and a second type of households must pay a transaction fee for

holding the longer bonds.

3 Comparing the Institutional Setup of the 1932 Operation and QE1

3.1 General Economic Conditions and Announcement of the Programs

In order to compare the effects of the purchase programs of the Federal Reserve during these two periods, it is necessary to ensure that the economies had similar characteristics. We provide evidence to show the remarkable similarities between the economies during the two episodes. The economy in the United States at the time of implementation of the two programs were very similar. The unemployment rate in April 1932 was 21.03%, and it had risen to 25.02% in August 1932. In the 2008-09 episode, the unemployment numbers were also rising, from 6.8% in November 2008 to 8.7% in March 2009. Real GDP had declined by more than 20% in 1932 since the start of the Great Depression, and in December 2008, real GDP in the U.S. had fallen by approximately 4% since December 2007. Table 1 shows the comparison between the two periods on two dimensions - the states of the economy, as well as the size of the Federal Reserve programs.

Other than the depressed states of output and employment, Treasury yields were at historically low levels in 1932, as they were in 2008. Cecchetti (1988) estimates the term structure of Treasury yields from 1929 to 1949 using raw data on the prices of Treasury securities outstanding reported in the New York Times. Using the Nelson and Siegel (1985) methodology, Cecchetti shows that between May and October 1932 (at the time of the

Federal Reserve operation), the three-month yields were between 10 and 25 basis points.[7]

3.1.1 The 1932 Operation

The Federal Reserve began its massive (for the time) open market purchases in April 1932. This was after two and a half years of recession in which the Fed had followed a very passive policy. It did not prevent three banking panics. Friedman and Schwartz (1963) attribute the Fed's failure to act to serious flaws in the organization of the System which impeded coordination between the Reserve banks and the Federal Reserve Board in Washington DC, especially after the death of Benjamin Strong in 1928. Meltzer (2003) largely attributes it to adherence to a flawed policy doctrine - the Burgess Rieffler Strong doctrine (a variant of the real bills doctrine) that relied on nominal interest rates and the level of discount window borrowing as policy guides. Others attribute it to adherence to the gold standard and the absence of a clear lender of last resort policy (Bordo and Wheelock 2013).

According to Friedman and Schwartz,[8] the Fed, under the leadership of Governor Harrison of the New York Federal Reserve voted to begin purchases of government securities on April 13, 1932 in the amount of $100 million per week for 5 weeks. Then on May 17, another $500 million was voted on.

Friedman and Schwartz argue that the Fed adopted this dramatic change in policy to forestall several radical pieces of legislation in the Congress including the Thomas bill which would have created $2.4 billion dollars in greenbacks and a veterans bonus. Meltzer (pp. 360) posits that the open market purchases would have been consistent with the Burgess Rieffler Strong doctrine since member bank borrowing was high as were short-term interest rates. He also states that the passage of the Glass Steagall Act of 1932 and the beginning of

[7] The three-month yield remained in this approximate range in the remaining period of Cecchetti's study.
[8] See pps 385-389.

Reconstruction Finance lending to troubled banks in February encouraged the Fed to act.

The policy was short lived. By July 1932 mounting opposition within the Federal Reserve System to continued purchases overwhelmed Harrison's pleas to continue. Many Fed officials, following real bills thinking, were worried that continued purchases would be inflationary and would stimulate an asset boom. They believed that the purchases had not encouraged the banks to lend as intended but instead they were just accumulating as excess reserves (Hetzel 2012 p.31).[9] Others worried that further purchases would severely reduce the System's holding of free gold and threaten the U.S. adherence to the gold standard. When the Congress recessed for the summer in July the Fed stopped the program.

Both Friedman and Schwartz and Meltzer provide evidence that the expansionary policy led to a turnaround in the economy[10]. They posit that had the Fed continued the policy that the Great Depression would have ended significantly earlier than it did.

3.1.2 Quantitative Easing in 2008-09

The 2007 financial crisis was the largest shock to global financial markets since the Depression. Bank were hit hard by enormous liquidity pressures, and as demands for cash from different sources peaked (counterparties, existing borrowers and short-term creditors), credit fell, and these markets froze.[11] By the third quarter of 2007, international financial institutions were reporting concerns with valuation and liquidations of US mortgage related assets, leading to sharp increases in the LIBOR rate. As tight credit conditions carried on

[9] Starting in February 1932, banks began reducing their borrowed reserves and increasing their excess reserves which grew from $44 million to $526 million in December 1932. Given that the banks had just experienced two years of liquidity panics, the build up of excess reserves was understandable (Hetzel 2012 p 31.).

[10] M2 stopped declining and flattened out; Federal Reserve Credit picked up as did bank credit. Industrial production and real GDP began expanding after a lag. Interest rates reversed their rise and dropped precipitously. See Bordo 2013.

[11] Strahan (2012), SF Economic Letters, Liquidity Risk and Credit in the Financial Crisis.

into 2008, Fannie Mae and Freddie Mac were placed under conservatorships and the Fed expanded existing liquidity programs, and introduced new ones, such as the Commercial Paper Funding Facility.[12] Concerns about the weakening state of the economy began to appear in the minutes and statements of the Federal Open Market Committee (FOMC) meetings in August 2007, and the first cut in the federal funds rate was implemented in September 2007 (from 5.25% to 4.75%). Successive statements continued to lower the federal funds rate, and the communications of the Federal Reserve noted, with increasing emphasis, that the strains in financial markets were increasing, consumer and business spending were softening and the housing market correction was intensifying. In March 2008, along with a further reduction in the federal funds rate, the FOMC also announced the Term Securities Lending Facility (TSLF) to promote liquidity in financial markets, and foster their functioning. The statements of September and October 2008 (which included a joint statement by the Federal Reserve, Bank of England, Bank of Canada, the Sveriges Riksbank, the Swiss National Bank and the ECB) continued to lower the federal funds rate, and the December 2008 statement finally reduced the rate to the zero-lower bound.

The timeline for the first QE program included several important dates, and these have been identified by Gagnon, Raskin, Remache and Sack (2010):

1. On November 25, 2008, the Federal Reserve announced creation of the Term-Asset Backed Securities Loan Facility "to support the markets for asset-backed securities collateralized by student loans, auto loans, credit card loans, and loans guaranteed by the Small Business Administration. The facility, developed jointly with the Treasury, was expected to be operational by February 2009, [...]." It also announced a program to purchase "up to $100 billion in direct obligations of housing-related government-

[12] Lopez (2009), Gauging Aggregate Credit Market Conditions, SF Fed Economic Letters.

sponsored enterprises and up to $500 billion in MBS backed by Fannie Mae, Freddie Mac and Ginnie Mae." This was undertaken to reduce the cost and increase availability of residential mortgage credit.

2. On December 1, 2008, Chairman Bernanke, in a speech at the Greater Austin Chamber of Commerce, Austin, Texas announced that "...although conventional interest rate policy is constrained by the fact that nominal interest rates cannot fall below zero, the second arrow in the Federal Reserve's quiver–the provision of liquidity–remains effective. Indeed, there are several means by which the Fed could influence financial conditions through the use of its balance sheet, beyond expanding our lending to financial institutions. First, the Fed could purchase longer-term Treasury or agency securities on the open market in substantial quantities. This approach might influence the yields on these securities, thus helping to spur aggregate demand [...]."

3. The FOMC statement on December 16, 2008, reiterated the Federal Reserve's commitment to purchase large quantities of agency debt and MBS. It further noted "...it [the Federal Reserve] stands ready to expand its purchases of agency debt and mortgage-backed securities as conditions warrant. The Committee is also evaluating the potential benefits of purchasing longer-term Treasury securities."

4. The January 28, 2009 statement noted the Federal Reserve's commitment to expand the quantity of purchases and the duration of the purchase program for agency debt and mortgage-backed securities, as conditions warrant.

5. The statement on March 18, 2009, announced the increase in the size of the Federal Reserve's balance sheet by purchasing up to an additional $750 billion of agency mortgage-backed securities. This bought the total purchases of these securities to up

to $1.25 trillion. It further increased its purchases of agency debt to a total of up to $200 billion. The Committee also decided to purchase up to $300 billion of longer-term Treasury securities over the next six months.

The subsequent FOMC statements in August, September and November 2009 announced gradual slowing down of these purchases.

3.2 Institutional Differences between Operations

Our main hypothesis is that the 1932 operation provides a natural experiment in monetary policy, and it can be used to analyze the first Quantitative Easing program. To support this claim, we identify the key similarities between the two episodes, as well as discuss the main differences in the institutional setups of the two economies.

Both episodes were conducted in the midst of severely depressed economic activity. These were large scale open market operations, and the magnitude of the bond purchase programs were unprecedented relative to the past bond purchase programs in both cases. The programs were initiated to boost the economy, and were not planned to continue indefinitely.

The key institutional differences between the implementation of the two programs were: (a) the operation of the Gold Standard in 1932 instead of a floating exchange rate, (b) the announcement of the size and duration of the program during the first QE episode in 2008-2009 and (c) the use of other unconventional policy tools in 2008-2009. While these aspects were important, we hypothesize that they do not make the comparison between the 1932 and 2008-2009 operations invalid.

The U.S. remained on the Gold Standard throughout the operation of the bond buying program, but there was considerable concern among Federal Reserve officials that the bond purchases would affect the commitment of the Fed to the Gold Standard. However, the

program did not threaten the credibility of the Federal Reserve or cause expectations of a devaluation. According to Bordo, Choudhri and Schwartz (2002), since the U.S. was a large open economy, with vast gold reserves, the expansionary monetary program would not cause markets to question the Federal Reserve's commitment to the Gold Standard. Hsieh and Romer (2006) find that there were no significant expectations of devaluation of the U.S. dollar (as measured by forward and spot exchange rates) in the spring of 1932. Thus, although there was disagreement among the Federal Reserve officials about the conduct of the program, it did not cause the Fed to lose any credibility in terms of its commitment to the Gold Standard.

The second difference between the programs is the provision of forward guidance in 2008-2009. While the size of the bond purchases were discussed in the Open Market Policy Conference (the precursor of the Federal Open Markets Committee), these discussions were not made public. Thus, the size and duration of program was not publicly announced. However, it did not go completely unnoticed. Hsieh and Romer (2006) discuss narrative accounts from different news sources, which reported the weekly balance sheet of the Federal Reserve. They find that business analysts were able to discern that the Federal Reserve was buying bonds at an accelerated pace, and that this program could help in stemming the deflationary spiral. Thus, financial markets understood that the program was ongoing in the second quarter of 1932.

Finally, the QE operation included the purchase of other assets (mortgage-backed securities). The Federal Reserve was also transitioning to the payment of an interest rate on excess reserves held by banks in 2008. Neither of these aspects were present during the Fed's 1932 operation. We will, therefore, only be comparing the Treasury bond-buying purchase programs of the Fed between 1932 and 2008-2009, and the effects of these operations on the

economy.

4 Analyzing Channels for the Effects of the Purchase Programs

Before analyzing the two programs, we discuss the channels through which these asset purchase programs are hypothesized to affect yields. The portfolio balance and signalling channels have been primarily used to explain the effects of the expansionary programs of the Federal Reserve. Here, we discuss the effects of the operations of 1932 and 2008-2009 on the nominal yield curve and its slope for U.S. Treasuries. In our analysis below, we focus on the Federal Reserve purchases of U.S. Treasury bonds of different maturities; although the 2008-2009 operation was significantly larger in the scope of securities that were involved, the 1932 operation was primarily concerned with Treasury bonds. In order to ensure a comparative analysis, we restrict our discussion to these securities.

4.1 Portfolio Balance Channel

The main thesis of the portfolio balance channel is that assets of different maturities are not perfect substitutes. As Gagnon et. al. (2010) and Bauer and Rudebusch (2013) note, the purchases of medium- and long-term securities by the Federal Reserve altered the supply of these bonds available to these private investors. As the holdings of the risk-free short-term bank reserves by the private investors increased, the yields on the bonds being purchased by the Federal Reserve would fall, to ensure that private investors are willing to make an adjustment in their holdings. Thus, the term premia (the largest component of risk premia) will be lowered, as the assets of longer duration are removed from the supply available to

private investors. In contrast, in a frictionless asset pricing model, a change in the supply of long-term or short-term bonds will not have an effect on Treasury bond yields. In this case, the term premia will be a function of the riskiness of the bonds, and the risk aversion of investors. Both these characteristics are unaffected by changes in the supply of bonds.

In order to examine the operation of the portfolio balance channel in these episodes, we first analyze the holdings of U.S. Treasury bills, notes and bonds by the Federal Reserve, as a fraction of the total holdings. As figure 1 shows, the fraction of the Federal Reserve's holdings of U.S. Treasury Notes increased from 10% of total holdings to more than 20%, between April and August 1932. The fraction of Bill holdings stayed fairly constant, fluctuating between 54% and 63%, and the fraction of Bond holdings *decreased* from 36% to 23%. Therefore, the largest purchases by the Federal Reserve during this episode. In contrast, during the 2008-2009 episode, the Federal Reserve's holdings of Notes (with 1 to 5 years to maturity) increased from 36% to 39% approximately, and the fraction of Bond holdings (with maturity 15 years or more) increased from 20% to 21% between July 2008 and March 2009. Thus, the operation by the Federal Reserve in 1932 was more significant on the medium-term securities, relative to the long-term operation, unlike the more recent 2008 operation. Both operations caused a compositional difference in the Bank's portfolio of securities. In section 5 below, we use the event-study methodology to examine the effects of changes in the portfolio composition of the Federal Reserve at a weekly frequency over the 1932 and 2008 operations.

To analyze the changes in the overall supply of these Treasury securities to the rest of the economy, and evaluate the contraction of supply effect, is also useful to consider the holdings of the Federal Reserve as a fraction of the total marketable debt outstanding from the Treasury. In the 1932 operation, the Bank's holdings of Treasury Notes averaged 13% of the total marketable debt issued in Notes, and Bond holdings were approximately 7% of

the total debt issued in Bonds. We also find that the Treasury was issuing more debt than before in the Great Depression: between December 1930 and December 1932, the issuances of notes and bonds increased by approximately 41% and 17.5% respectively.[13] In contrast, in the 2008-09 episode, Fed's holdings of Notes and Bonds were 6% and 33% of the total. Thus, the Federal Reserve's holdings of Bonds during the latter episode were more than four times its holdings in the 1932 operation.

4.2 Signaling Channel

Following the Expectations Hypothesis, the long yields can be expressed as a function of average expected short yields and the risk premium. The signaling channel focuses on the effect of the expansionary programs on the expectations of the short yields: the large-scale purchases of Treasury securities may be interpreted by the private economy as a signal that the Federal Reserve expects the economic conditions to remain weak, and this would lower the expectations of future short-term yields. Bauer and Rudebusch (2013) argue that the signaling channel not only affected the expectations of investors about future short term rates, but it also lowers the term premium. Using DTSM with risk correction models, the authors find that over a set of eight announcements that introduced and implemented the LSAP programs, the ten-year yield dropped by 89 b.p, and the five-year yield declined by 97 b.p. For the ten-year yield, the range of the signaling effect is estimated to be between 30% and 35%; for the five-year yield, signaling contributes between 32% and 45% of the total decline observed in the actual level of yields. The remaining is attributed to the change in the term premia. This decomposition between the change in expectations and term premia can be heuristically thought of as the relative importance of the signaling and portfolio balance

[13] These numbers are based on the bills, notes and bonds issued as public debt, recorded in the Monthly Statement of Public Debt. The archived records are obtained from Treasury Direct.

channel.[14] Additionally, Swanson and Williams (2014) find that between 2008 and 2011, while the federal funds rate was at the zero-lower bound, the Federal Reserve was able to influence interest rates for medium and long-term Treasury securities by managing policy expectations of investors and conducting large scale purchases of assets. The authors do not distinguish between the importance of these two channels, but find that sensitivity of the medium and long-term yields to news between 2008 and 2011 was very similar to the responses of these yields to surprise macroeconomic news between 2004 and 2006. This is attributed to the ability of the Federal Reserve to influence expectations for upto the two-year horizon through its communications and implementation of the purchase programs. Finally, Woodford (2012) finds that there was strong model-free evidence of the signaling channel during the purchase programs, as do Campbell et al. (2012).

During the 1932 episode, the sudden implementation of the Federal Reserve asset purchase program, along with very few indications of how low these were expected to remain, implied that the signaling channel was, at best, very weak. While it is difficult to empirically distinguish between the effects of the portfolio balance and signaling channels without the availability of overnight swaps and other instruments, the institutional setup of the 1932 operation lead to us to conclude that the channel was not important during this operation

4.3 Additional Channels

There are other channels through which the Federal Reserve's operation would have an effect on the term structure of yields. Most of these channels focus on the changes in the relative supply of safe and risky securities: during the 2008-09 operation, the Bank was also purchasing other agency debt, such as Mortgage Backed Securities (MBS).

[14] Bauer and Rudebusch (2013) point out the cases in which this decomposition may not be fully applicable.

According to the Duration Risk channel[15], if the investors have a preference for an asset of specific duration (irrespective of whether it is the U.S. Treasury or a corporate bond of the same maturity), then the QE program will lead to a reduction in asset yields. During the 1932 operation, the purchases of the Federal Reserve were concentrated on Treasury securities, and there were no significant assets of comparable duration and security that were available to investors. Thus, this channel would not be significant during the 1932 episode.

The Liquidity channel implies that the expansionary operation by the Federal Reserve involves increasing the holdings of medium- and long-term bonds, while paying for the operation by increasing reserve balances. The higher reserve balances act as extra liquidity in the hands of the investors, and will increase yields. According to Vissing-Jorgensen and Krishnamurthy (2011), the effect of the Liquidity channel during the QE period was not to increase yields on Treasury debt. However, the authors note that the decrease in yields on Treasury securities was smaller than the decrease in yields on less liquid assets, such as agency debt.

The Safety channel is a special case of the preferred habitat channel, but only in the space of safe bonds and assets. Within the set of the safest assets available to private investors in the economy, as the Federal Reserve's holdings of the long-term Treasury securities increases, it lowers the yield on the ultra safe or investment grade securities, relative to less safe assets in which the operation is conducted. As the relative comparison is difficult in the 1932 episode, due to the scant availability of comparable securities, we conclude that this channel was not significant during this episode.

[15] This is similar to Vayanos and Vila's preferred habitat model.

5 Effects of the 1932 and QE1: Event Study Methodology

We use the event study methodology to examine the effects of the Federal Reserve operations on the term structure of yields. To our knowledge, the 1932 operation has not been analyzed from this perspective before. For our analysis, we construct a weekly series of the holdings of the Federal Reserve, along with corresponding yields of different maturities, using data from the Federal Reserve Bulletins and Annual Reports. Although the most recent applications the event study methodology to analyses of the Quantitative Easing programs use time series at the daily frequency, obtaining this level of frequency for the 1932 operation is difficult. However, the use of a weekly time series allows us to examine the Federal Reserve operation in a more rigorous manner, as changes in expectations of inflation and the federal funds rate are less likely over this time horizon, relative to a monthly or quarterly series[16].

The other main difference between the current event-study methodologies and our approach is the determination of the dates around which the effects on yields are being examined. Studies such as Gagnon et al. (2010) and Swanson (2011) determine key dates on which the Federal Reserve announcements were made, and examine the effect on yields in one- and two-day windows around the announcements These dates corresponds to announcements about the size of the program, and explicit indications about the Federal Reserve's expectations about how long the operation would continue. However, in the 1932 episode, there was no equivalent forward guidance about the program, its size or the duration. Therefore, to analyze the effects of the operation, we choose the dates that correspond to significant change in the Federal Reserve's holdings of Treasury securities. These significant changes

[16] These time series are more common the literature for analyzing the Great Depression.

are defined as a more than 5% change in the Federal Reserve's holdings of the Treasury security, relative to the week before. In the robustness section below, we also consider other benchmarks.

Finally, in order to compare the QE1 program with the 1932 operation, we estimate the effects of QE1 on the term structure of yields using both strategies: first, we present our analysis using the announcement dates of Gagnon et al. (2010). In the robustness section below, we use the dates on which there were changes in the Federal Reserve's of more than 5%.[17]

5.1 Yields and Holdings during the 1932 Operation

Table 2 shows the changes in the Fed's holdings of the Treasury notes and bills during the 1932 episode. The weeks for which the holdings of the Treasury Notes by the Federal Reserve Board changed by more than 5% (in either direction) are highlighted. The corresponding level and changes in the 3-5 year Treasury yields is shown in columns 4 and 5. A continuous series on weekly data for the yields on Bills is not available. Between April and August 1932, there were 10 weeks during which the Federal Reserve's holdings of Notes changed by more than 5% relative to the preceding week. The holdings of Bills recorded large changes in 6 weeks over the 24 month period, and the holdings of bonds changed significantly in 4 different weeks, as shown in table 3. The evolution of the Federal Reserve's holdings of these Treasury securities, and their respective yields are also shown in figure 1.

[17] These dates will be different from the announcement dates - but if the announcements are explicit, then financial markets will internalize the changes, and expectations will adjust at the time of the announcement. Therefore, we should not expect to see too much action around the dates when the Fed's holdings actually changed during the QE1 period

The Importance of Different Channels

Since there were no significant announcements during the 1932 episode, we hypothesize that the portfolio balance channel was most significant. The reduction in supply of medium term securities to the domestic economy, as the holdings of the Bank increased, lowered yields in successive weeks. The lack of another security of comparable characteristics in terms of safety makes it difficult to analyze whether the duration risk channel was important.

5.2 Yields and Holdings during QE1

Using the announcement dates discussed in section 3.1.2 above, we determine the weekly changes in the yields for Bonds and Notes around the events. The cumulative changes for the ten-, five- and one-year yields are computed, and the former experiences the largest decline, as shown in table 4. These estimates are comparable with other analyses, such as Vissing-Jorgensen and Krishnamurthy (2012) and Gagnon et al. (2010). Unlike those studies, we focus on the weekly changes to use a similar time period for computing the changes as the 1932 operation.

The Importance of Different Channels

The portfolio balance and signaling channels are both important during this episode. The explicit forward guidance by the Federal Reserve communicated its strategy about the size and implementation of the program, and had significant consequences for the expectations of financial markets. The QE1 announcement on March 18, 2009 was especially significant. According to Campbell et al. (2012), on this day, although the ten-year yield fell by 51 b.p. in a one-day window around the announcement, there was an opposite reaction in the expectations of financial markets. The authors decompose the change in the ten-year yield

into a factor attributed a change in the target federal funds rate, and the factor associated with a change in the path of the rate. This latter factor *increased* by 32 b.p. around the QE1 announcement, indicating that the markets interpreted the FOMC statement as implying that the economy would recover faster than previously expected. This implies that the federal funds rate lift-off was expected to be earlier than anticipated. In contrast, for the QE2 announcement, the signaling effect of the FOMC statement was that markets expected the federal funds rate to remain low (and the path factor was positively correlated with the change in the actual yields). Thus, the QE1 announcement was distinctly different from the successive announcements in the manner in which it affected financial market expectations.

6 Consequences for the Real Economies in 1932 and 2008-09

The event study methodology above presents evidence that the two purchase operations had significant effects on Treasury yields. In the present section, we use a general equilibrium framework to further explore the channels through which the monetary policy actions affected the real economy. To do this, we use the modeling framework of Andrés, López-Salido and Nelson (2004) and Chen, Cúrdia and Ferrero (2012). This is a segmented markets model in which there are two types of households: the unrestricted households trade in long and short bonds, and the restricted only trade in long term bonds. The unrestricted households are required to pay a transaction cost for every long bond purchased. This transaction cost for long bonds gives rise to a risk premium, which has two components: the first arises because the households face a portfolio adjustment cost (this is modeled as a function of the relative quantity of the short and long bonds). The second component is an exogenous error. This

model is used to analyze the 1932 episode. We first present the optimization decisions and policy rules of the households, firms, central bank and the government. Following a brief description of the numerical strategy, we analyze the two programs using the model.

6.1 Model

6.1.1 Households

A continuum of households $i \in [0,1]$ have access to long and short-term bonds. Financial market segmentation is introduced by assuming there are two types of households: the unrestricted households can participate in long and short-term bond markets; the restricted households can only buy long-term bonds. Both types of households derive utility from consumption, and disutility from labor. There are identical in all respects, other than their access to financial markets. The utility function of household $i \in \{u, r\}$ is:

$$E_t \sum_{j=0}^{\infty} \beta_i^j b_{t+j}^i \left[\frac{1}{1-\sigma_i} \left(\frac{C_{t+j}^i}{Z_{t+j}} - h \frac{C_{t+j-1}^i}{Z_{t+j-1}} \right)^{1-\sigma_i} - \frac{\varphi_{t+j}^i \left(L_{t+j}^i (k) \right)^{1+\nu}}{1+\nu} \right]. \quad (1)$$

Here β_i^j is the discount factor of type j , b_t^i is the preference shock, σ_i is the coefficient of relative risk aversion, C_t^i is the consumption, h is the habit formation parameter, φ_t^i is the labor supply shock and ν is the inverse of the labor supply elasticity.

The budget constraint of the unrestricted household is:

$$P_t C_t^u + B_{S,t}^u + (1+\zeta_t) P_{L,t} B_{L,t}^u \leq R_{S,t-1} B_{S,t-1}^u + \sum_{j=1}^{\infty} \kappa^{j-1} B_{L,t-j}^u + W_t^u (k) L_t^u (k) + \mathcal{P}_t - T_t^u. \quad (2)$$

Here P_t is the price of the consumption good, $B_{S,t}^u$ are the holdings of the one-period (short) bond, ζ_t is the transaction cost paid by the unrestricted household to purchase the long

bond, $P_{L,t}$ and $B^u_{L,t}$ are the price and holdings of the long-term bond respectively, κ is the rate of exponential decay of the long-term bond, W^u_t is the wage paid by firm k, $\mathcal{P}_t$ is the sum of profits accruing to the household from ownership of final, intermediate and capital producers. The household pays lumpsum taxes T^u_t. The constraint of the restricted household does not include the transaction cost ζ_t for the purchase of long-term bonds, along with their corresponding choices of consumption, bond holdings, labor supply and tax burden.

The households optimally choose consumption, holdings of long and short-term bonds and labor supply. The Euler equations are central to the effects of the financial market segmentation, and are shown here. The remaining optimizing conditions are shown in the appendix.

For the short-term bond, the Euler equation is:

$$1 = \beta_u E_t \left[\frac{MU^u_{t+1}}{MU^u_t} \frac{R_{S,t}}{\Pi_{t+1}} e^{-\gamma - z_{t+1}} \right], \tag{3}$$

where MU^u_t is the marginal utility of consumption, and $e^{-\gamma - z_{t+1}}$ accounts for growth in productivity. Finally, $\Pi_{t+1} = P_{t+1}/P_t$. For the long bond, the presence of transaction costs for the unrestricted households modifies the Euler equation to:

$$1 + \zeta_t = \beta_u E_t \left[\frac{MU^u_{t+1}}{MU^u_t} \frac{R_{L,t}}{\Pi_{t+1}} \frac{P_{L,t+1}}{P_{L,t}} e^{-\gamma - z_{t+1}} \right]. \tag{4}$$

Finally, the pricing equation for the restricted households is given by:

$$1 = \beta_r E_t \left[\frac{MU^r_{t+1}}{MU^r_t} \frac{R_{L,t}}{\Pi_{t+1}} \frac{P_{L,t+1}}{P_{L,t}} e^{-\gamma - z_{t+1}} \right]. \tag{5}$$

Following Chen, Cúrdia and Ferrero (2012), the transaction cost is modeled as a function of

the ratio of long and short-term debt held by the public, and an exogenous error term:

$$\zeta_t = \zeta \left[\frac{P_{L,t} B_{L,t}}{B_{S,t}}, \varepsilon_{\zeta,t} \right]. \tag{6}$$

Assuming that the function ζ and its first derivative are positive, a reduction the outstanding debt held by the public will result in a fall in the yield on long-term bonds. This is the mechanism through which asset purchases by the central bank will affect the term structure of yields: a change in the holdings of outstanding debt will affect the savings decisions of the restricted households through a change in the long-term yield, and consequently, output and inflation in the economy.

6.1.2 Firms

There are three types of firms in the economy: capital goods producers, which are competitive and make investment decisions. These firms rent capital to intermediate goods producers, and the amount of capital rented is determined by the utilization rate chosen by the capital goods producer. The intermediate goods producers combine labor hired from households and the rented capital to produce output using the Cobb-Douglas production function. In the production of intermediate goods, technology is assumed to be labor augmenting. Prices of intermediate goods are set using the Calvo staggered price mechanism. The last type of firms are the perfectly competitive final goods producers: these combine differentiated intermediate goods into a homogeneous product, with a price markup. The firms' optimizations are presented in the appendix.

6.1.3 Central Bank

Orphanides (2003) analyzes the historical behavior of the interest rates of the Federal Reserve, and finds that for the 1920s, the interest rate rule could be well approximated using the Taylor rule. Taylor (1999) further discusses how during the international gold standard era, the interest rate would react positively to change in inflation and real output. Therefore, the central bank is assumed to set the interest as:

$$\frac{R_{S,t}}{R_S} = \left(\frac{R_{S,t}}{R_S}\right)^{\rho_m} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \left(\frac{Y_t/Y_{t-4}}{e^{4\gamma}}\right)^{\phi_y}\right]^{1-\phi_m} e^{\varepsilon_{m,t}}. \tag{7}$$

The Taylor parameters are $\phi_\pi > 1$, and $\phi_y \geq 0$. The interest rate smoothing parameter $\rho_m \in (0,1)$.

6.1.4 Government

The government finances its purchases by collecting lump-sum taxes and issuing long and short-term bonds:

$$B_{S,t} + P_{L,t}B_{L,t} = R_{S,t-1}B_{S,t-1} + (1 + \kappa P_{L,t})\, B_{L,t-1} + P_t G_t - T_t. \tag{8}$$

Long-term debt is issued in non-zero supply, and the real value of this debt assumed to evolve as:

$$\frac{P_{L,t}B_{L,t}}{P_t Z_t} = \left(\frac{P_{L,t-1}B_{L,t-1}}{P_{t-1}Z_{t-1}}\right)^{\phi_B} e^{\varepsilon_{B,t}}.$$

The issuance of long-term debt is financed according to the following fiscal policy rule:

$$\frac{T_t}{P_t Z_t} - \frac{G_t}{Z_t} = \left(\frac{P_{L,t-1}B_{L,t-1}}{P_{t-1}Z_{t-1}}\right)^{\phi_T} e^{\varepsilon_{T,t}}. \tag{9}$$

Following Davig and Leeper (2006), the fiscal parameter $\phi_T > 0$

6.2 Equilibrium strategy and Numerical Solution

In equilibrium, the households and firms maximize utilities and profits respectively, subject to the corresponding budget constraints. The first-order log linearized model is estimated using Bayesian methods, following the strategy of Cúrdia, Chen and Ferrero (2012).

6.2.1 Data

In order to estimate the model, the relevant macroeconomic time series are constructed for January 1920 to December 1934. Balke and Gordon's (1986) Real GNP and GNP deflator series are used for the output and inflation measure. Population numbers are taken from the U.S. Census Bureau. The construction of the number of labor hours supplied entails two different data sources. From Beney's (1936) study, the series of average hours worked per week per worker in manufacturing is used to construct average actual hours per quarter per wage earner. This is multiplied with the average number of workers in manufacturing, available from the Bureau of Labor Statistics. Yields on bonds and notes are taken from the Banking and Monetary Statistics for 1914-1941 publication of the Federal Reserve, and the Federal Reserve's holdings of Treasury debt is constructed from the tables on Factors affecting bank reserves and condition statement of the Federal Reserve Banks.

6.2.2 Parameters

We use the period 1920Q2 to 1932Q1 for estimation. In the numerical simulations for the 1932 episode, the prior on output growth in steady state is assumed at 1%, on inflation it is 1%, and the standard deviation is 0.5. The degree of segmentation is assumed at 0.7,

with a standard error of 0.2. Using the data on the Federal Reserve's holdings of Treasury securities, the average duration of debt is found to be approximately 15 quarters, and the steady state level of debt is 15% of GDP. The priors on the remaining parameters are shown in table 5.

We obtain mean posterior estimates of market segmentation of 0.76[18]. Table 6 shows the posterior estimates obtained from our exercise. This degree of segmentation confirms our original hypothesis of a large degree of financial segmentation during the 1920s. Cúrdia, Chen and Ferrero (2012) estimate the market segmentation parameter to be 0.94, and find significantly smaller effects of the asset purchase program of the Federal Reserve in the posterior distribution.

6.3 Simulations

In our benchmark simulation presented in figure 5, we consider an increase of $1 billion of long-term security holdings of the Federal Reserve. This was the initial increase in the Federal Reserve's holdings, and we first analyze the case of the effect on the economy if the purchases had stopped there. Although the Bank did not explicitly follow a policy of setting the Federal Funds Rate at the zero-lower bound, as noted in sections 2 and 5 above (and table 2) the Treasury yields were effectively at this bound. Thus, we assume that the zero-lower bound was active for two years after the start of the operation. Consistent with the historical experience, the operation is only assumed to last for two quarters. The Fed purchases assets in the first quarters, and divests these in the second. Given the unexpected nature of the operation, and no indications that it would continue, we assume that agents

[18] Following Cúrdia et al. (2012), the posterior distribution is obtained in the following way: after obtaining the posterior mode, the normal approximation around the mode is used to form a jump distribution. This is used to generate a sample of parameter vector draws representative of the posterior, based on the Metropolis random walk MCMC simulation process.

only expect the operation to last for this period. In this simulation, the Fed is assumed to not hold the assets on its balance sheets. Following an increase in the Federal Reserve's holdings of the long-term securities, we observe approximately a 0.07% increase in output growth, a decline of 12 b.p. in the long-term yield.

Figure 6 considers an alternate scenario: suppose the Federal Reserve had purchased assets over two quarters, held onto these on its balance sheet for another two, and then divested its holdings over the remaining two quarters. This is similar to the announcement structure followed during the QE operation. The real effects are significantly larger: we find a 0.5% increase in output growth, and the long-term yield declines by 23 b.p. Under this simulation, the agents in the economy are assumed to fully understand the path of purchases announced by the central bank. These results suggest that while the response of consumption and inflation to a change in the holdings of long bond results due to the response of the risk premium to bond holdings, the forward-looking behavior of agents leads to significant effects of announcements. Thus, our findings indicate that the risk premium as well as the signalling channels are important in the transmission of the effects of changes in bond holdings to the real economy.

Our next set of simulations considers the effects of lengthening the duration of debt. This is increased to 20 quarters (an increase of approximately 1 year relative to the benchmark), and the results are shown in figure 7. Ceteris paribus, the open-market purchase has a smaller effect on the risk-premium as well as output growth and the long-term yield. Increasing the steady state level of debt to 20% of the GDP has similar effects, and these are shown in figure 8.

These results suggest that although the 1932 operation was significantly smaller in magnitude than the QE program, it had substantial effects on the economy. For the LSAP

program conducted by the Fed during the crisis of 2008, Cúrdia, Chen and Ferrero (2012) find that the effect on output growth was approximately 0.13%.

7 Conclusion

We find that the 1932 open market operations conducted by the Federal Reserve during the Great Depression, were effective in lowering Treasury yields and boosting output growth. The decomposition of the Federal Reserve's balance sheet over the operation shows that the largest increase in the Bank's holdings of Treasury securities at the medium end of the term structure (i.e., for Treasury notes). Our event study analysis indicates significant responses of Note yields around the weeks of the largest increases in the Federal Reserve's holdings. We then investigate whether the changes in the Bank's portfolio composition of assets can have real effects on the economy. There are several indicators which suggest financial market segmentation during the 1920s and 30s, and we use a segmented markets approach to model the effects of changes in portfolio composition. One of the agents in the economy are subject to transactions cost while purchasing the long-term bonds, while the other agents are restricted to holding long bonds. Bayesian estimates of the model indicate a significant degree of market segmentation, and we find relatively large responses of output and inflation following the purchase of longer-term securities by the central bank. Our main conterfactual simulation suggests that if the Federal Reseve had announced the operation and conducted the operation over a longer period, the effects on the real economy would be magnified. In our forward-looking model, the provision of forward guidance by the Bank leads households to expect the changes in risk premium (resulting from the decline in holdings of the longer-term security) to persist for longer.

Our results suggest several dimensions that can be explored further. First, we have assumed that the policy rate would remain at the zero-lower bound for two years following the operation. While this is observed ex-post in the data, the agents' ex-ante expectation that the short rate will remain in this corridor implies interaction effects between the purchase operation and the zero-lower bound regime. We are currently investigating the effects of the zero-lower bound on the real economy in the context of our model. Second, our counterfactual simulation assumes that agents in the 1932 economy would have assumed the Federal Reserve's announcement of the purchase operation to be fully credible, and form expectations accordingly. However, this may not have been the case. Thus, we will be exploring the effects of the purchase operation for the case where the operation was a surprise to the agents in the subsequent periods as well (in addition to the period of the announcement). This will allow us to consider the effects of forward guidance in a more comprehensive manner. Third, we have assumed that the central bank followed a Taylor rule during the 1932 episode when the Gold Standard was operational. While the Taylor rule has been used in the literature in this period by Orphanides (2003) and Taylor (1999), additional research is required to consider the effects of the operation under the assumption that the gold standard can be approximated by a price-level targeting regime. Finally, we have abstracted from the effects of paying interest rate on excess reserves in our model. This will be considered as a part of our future research agenda.

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Table 1: Comparison of the 1932 and 2008 Economies

Characteristic	**1932**	**2008**
Real GDP	787,518 million	14,833,557 million
Unemployment	21.03%-25.02%	6.8%-8.7%
Size of the program:		
% change in Bills	114%	$-0.05\%^a$
- % change in Notes	370%	$7\%^b$
% change in Bonds	32%	-1.5%
As a fraction of		
U.S. Treasury Marketable Debt:		
Short term	32.5%	2.1%
- Medium term	67.5%	5.8%
Long term	22.9%	7.8%

Notes: The real GDP series is evaluated at 2009 dollars, on an annual basis. The unemployment numbers are monthly and seasonally adjusted. a : This is the average change in the Federal Reserve's holdings of bills with maturity 15 days or less, 15 to 90 days and 91 days to 1 year; b : this is the change in the Federal Reserve's holdings of Notes of maturity 5 to 10 years. The last row shows the change in the fraction of different Treasury securities of the Federal Reserve, as a fraction of Marketable Debt between November 2008 and May 2009.

Table 2: Fed's holdings of Notes and Bills and Corresponding Yields

Week	% change in Bill Holdings	% change in Note Holdings	Yields levels on 3-5 year notes	Changes in yields on 3-5 year notes (in b.p.)
April 27, 1932	**15.9**	**11.7**	0.64	**-36**
May 4, 1932	**10.7**	**16.5**	0.53	**-11**
May 11, 1932	0.7	**38.2**	0.56	**3**
May 18, 1932	**12.8**	**7.6**	0.46	**-10**
June 15, 1932	2.7	**11.7**	0.2	**8**
June 22, 1932	0.7	**15.2**	0.4	**20**
June 29, 1932	2.1	**19.3**	0.53	**13**
August 3, 1932	-4.3	**20.3**	0.29	**3**
August 10, 1932	-2.1	**8.7**	0.12	**-17**
August 17, 1932	-1.7	**5.1**	0.25	**13**
Cumulative change				-14

Note: These estimates are based on weekly data.

Table 3: Fed's holdings of Bonds and Corresponding Yields

Week	% change in Bond Holdings	Yields levels on Bonds	Changes in yields on Bonds (in b.p.)
April 20, 1932	7.8	3.59	-8
May 25, 1932	5.4	3.82	8
June 1, 1932	5.9	3.85	3
June 8, 1932	8.4	3.84	-1
Cumulative change			2

Note: These estimates are based on weekly data.

Table 4: Response of Yields around the QE1 Announcement Dates

Week	Change in yields on 10-year Bonds	Change in yields on 5-year Notes	Changes in yields on 1-year Notes
November 25, 2008	-28	-6	-3
December 1, 2008	-44	-43	-24
December 16, 2008	-18	-20	-1
January 28, 2009	19	16	6
March 18, 2009	-17	-18	-6
Cumulative change	-88	-71	-28

Note: These estimates are based on weekly data.

Table 5: Estimates from the Prior Distribution

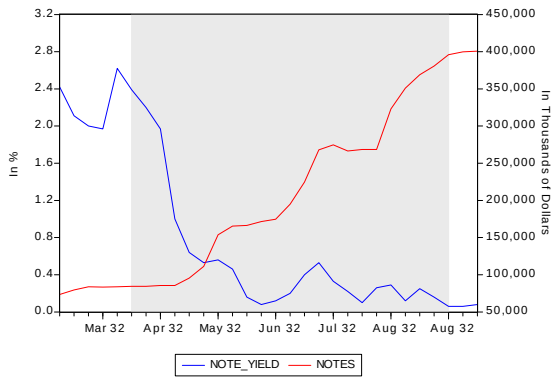
Coeff	Dist	5%	Median	95%	Coeff	Dist	5%	Median	95%
400γ	G	0.3416	0.9180	1.9384	χ_{wu}	B	0.2486	0.6143	0.9024
400π	G	0.3416	0.9180	1.9384	ν	G	1.2545	1.9585	2.8871
$400(\beta_u^{-1}-1)$	G	0.6272	0.9792	1.4436	ζ_w	B	0.3351	0.5000	0.6649
400ζ	G	0.2558	0.5657	1.0614	ζ_p	B	0.3351	0.5000	0.6649
B^{LMV}/B	G	0.6953	0.9867	1.3501	ϕ_T	G	0.7825	1.4448	2.4058
S''	G	2.5090	3.9170	5.7743	ρ_r	B	0.5242	0.7068	0.8525
a''	G	0.0683	0.1836	0.3877	ϕ_π	G	1.0164	1.7026	2.6453
h	B	0.4302	0.6029	0.7597	ϕ_y	G	0.1366	0.3672	0.7754
σ_u	G	0.6832	1.8360	3.8768	ρ_z	B	0.0976	0.3857	0.7514
σ_r	G	0.6832	1.8360	3.8768	ρ_μ	B	0.5701	0.7595	0.8971
$100\zeta'$	G	0.3067	1.2846	3.4294	ρ_b	B	0.5701	0.7595	0.8971
ω_u	B	0.3214	0.7334	0.9646	ρ_ϕ	B	0.5701	0.7595	0.8971
Ξ^u/Ξ^r	G	0.3416	0.9180	1.9384	ρ_B	B	0.6146	0.8135	0.9389
C^u/C^r	G	0.3416	0.9180	1.9384	ρ_ζ	B	0.6146	0.8135	0.9389
ρ_g	B	0.5701	0.7595	0.8971	σ_μ	IG1	0.1663	0.3433	1.2367
σ_z	IG1	0.1663	0.3433	1.2367	σ_B	IG1	0.1663	0.3433	1.2367
σ_{λ_f}	IG1	0.1663	0.3433	1.2367	σ_ϕ	IG1	0.1663	0.3433	1.2367
σ_b	IG1	0.1663	0.3433	1.2367					

Table 6: Estimates from the Posterior Distribution

Coeff	Mean	SE	5%	95%	Coeff	Mean	SE	5%	95%
400γ	0.6179	0.3556	0.1804	1.3250	χ_{wu}	0.2936	0.0993	0.1450	0.4988
400π	1.4260	0.7299	0.3725	2.6751	ν	1.9388	0.4955	1.2326	2.7276
$400(\beta_u^{-1}-1)$	1.4826	0.1991	1.1637	1.8232	ζ_w	0.7769	0.0236	0.7338	0.8168
400ζ	0.9253	0.3097	0.5434	1.5123	ζ_p	0.8017	0.0277	0.7626	0.8492
B^{LMV}/B	1.4920	0.1094	1.3181	1.6700	ϕ_T	1.1026	0.2118	0.7862	1.4645
S''	7.0017	0.8785	5.7809	8.4352	ρ_r	0.7611	0.0246	0.7254	0.8080
a''	0.0911	0.0021	0.0875	0.0943	ϕ_π	1.0457	0.0272	1.0059	1.0929
h	0.8729	0.0215	0.8363	0.9036	ϕ_y	0.4369	0.0340	0.3877	0.4950
σ_u	1.6409	0.1463	1.3758	1.8528	ρ_z	0.1728	0.0591	0.0791	0.2810
σ_r	1.0751	0.3069	0.5824	1.6119	ρ_μ	0.6976	0.1261	0.4850	0.8860
$100\zeta'$	0.3635	0.0729	0.2479	0.4884	ρ_b	0.9103	0.0378	0.8370	0.9641
ω_u	0.7624	0.0363	0.7098	0.8292	ρ_ϕ	0.8381	0.0246	0.7967	0.8765
Ξ^u/Ξ^r	0.4669	0.1518	0.2374	0.7325	ρ_B	0.6528	0.0470	0.5735	0.7340
C^u/C^r	0.5370	0.1531	0.2822	0.8091	ρ_ζ	0.9507	0.0069	0.9400	0.9632
ρ_g	0.7733	0.0810	0.6126	0.8938	σ_μ	0.8109	0.1480	0.5831	1.0697
σ_z	1.8703	0.2267	1.5628	2.3089	σ_B	14.2339	0.5736	13.2389	15.0704
σ_{λ_f}	1.2286	0.2656	0.8542	1.6881	σ_ϕ	1.1709	0.2943	0.6266	1.6530
σ_b	3.1861	0.4661	2.4594	3.9191					

Figure 1: US Treasury Notes and Yields

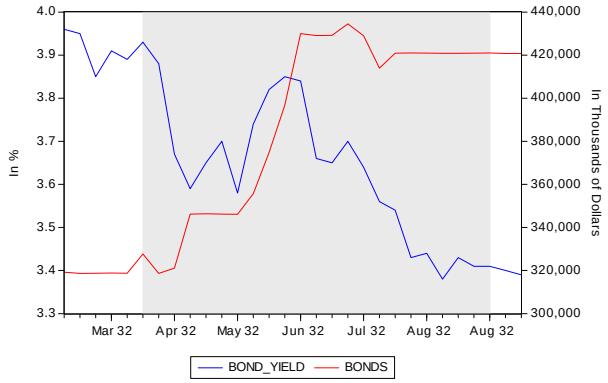
1932



QE1

Figure 2: US Treasury Bonds and Yields

1932



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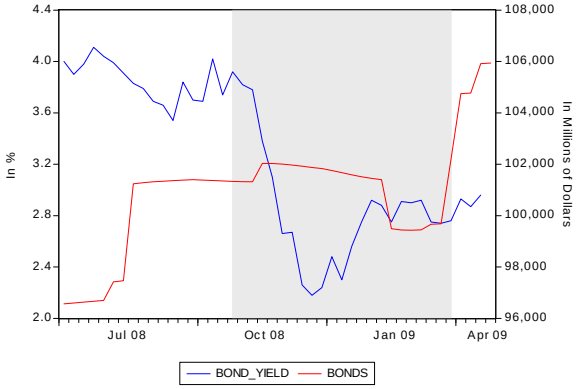
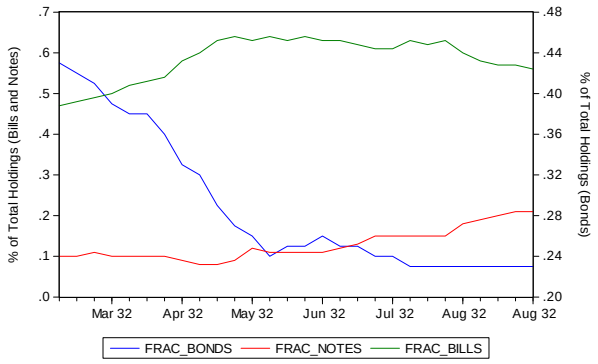


Figure 3: Treasury Holdings of the Federal Reserve as a Fraction of Total Holdings

1932



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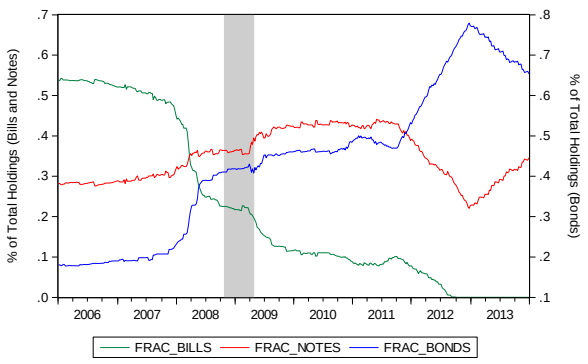
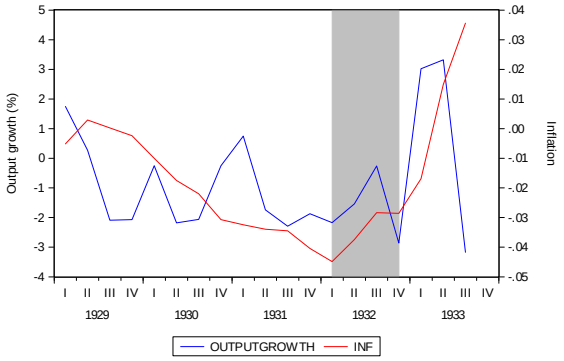


Figure 4: Output growth and Inflation

1932



QE1

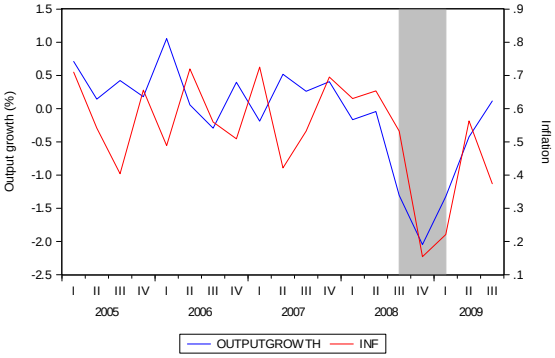
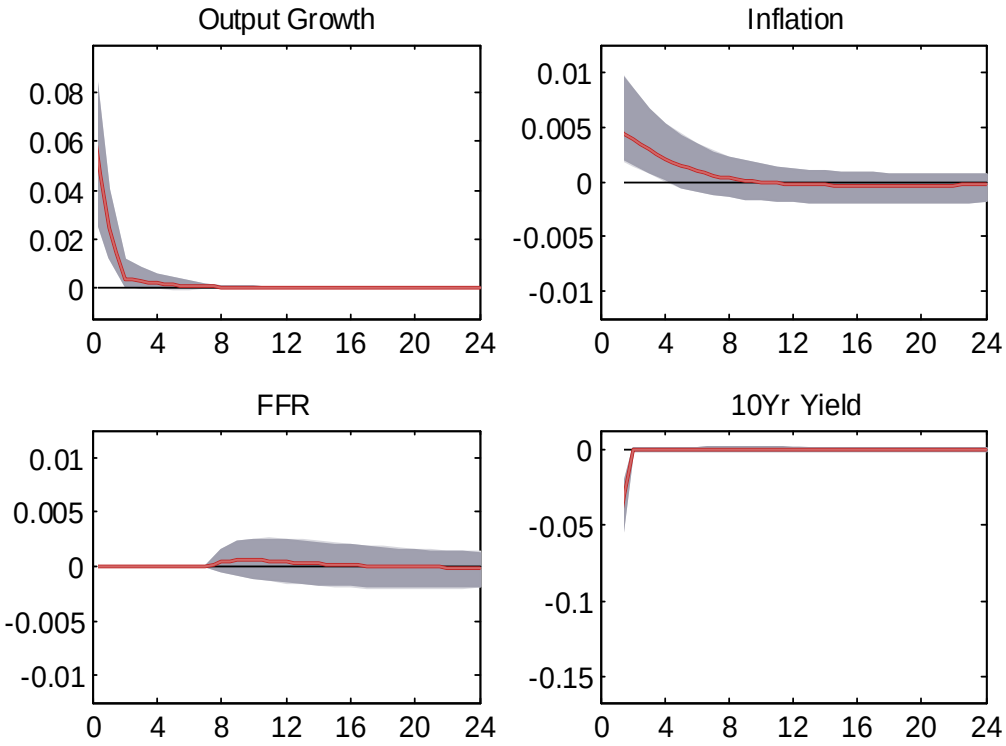


Figure 5: Effects of Treasury bond purchases by the Federal Reserve

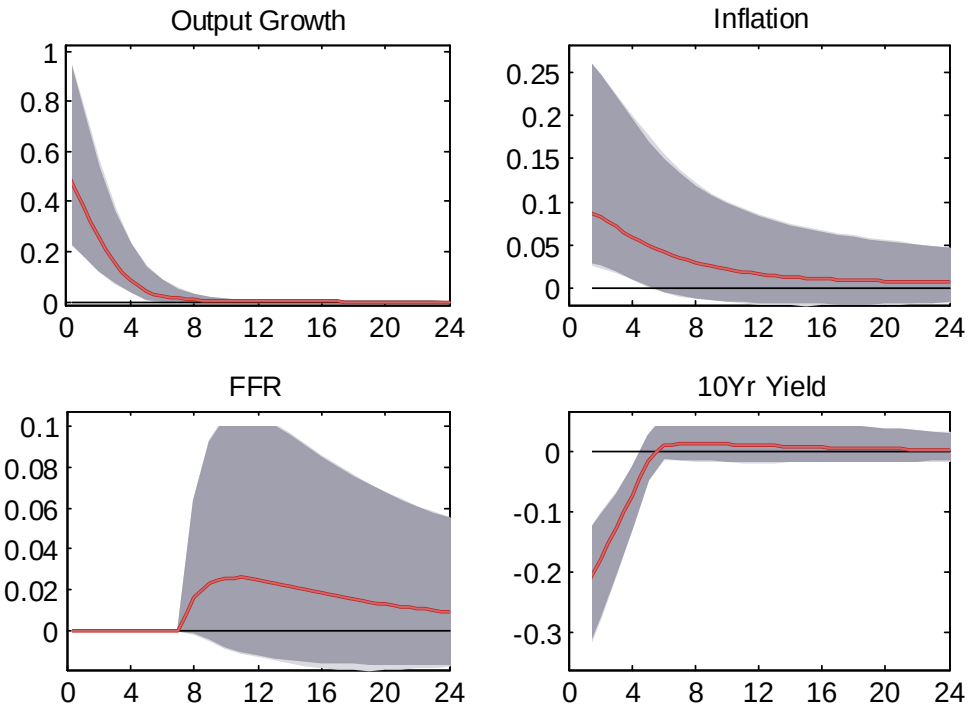
(Benchmark)



Notes: In this simulation, the average duration of debt is 15 quarters, and the purchase operation lasts for one quarter. The Fed then divests its holdings over the next quarter. The shaded regions show the 90 percent confidence bands. The zero-lower bound operates for 8 quarters.

Figure 6: Effects of Treasury Bond purchases by the Federal Reserve

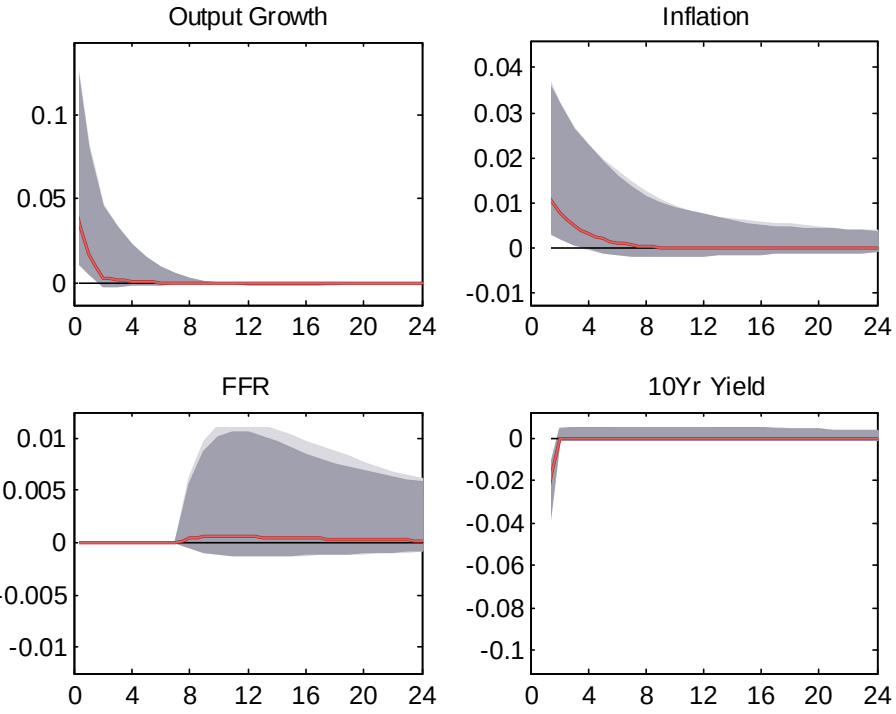
(Long-term securites are not immediately divested)



Notes: In this simulation, the average duration of debt is 15 quarters, and the purchase operation lasts for two quarters. The Fed holds onto the long-term assets for two quarters, and then divests these over the next two quarters. The shaded regions show the 90 percent confidence bands. The zero-lower bound operates for 8 quarters.

Figure 7: Effects of Treasury Bond purchases by the Federal Reserve

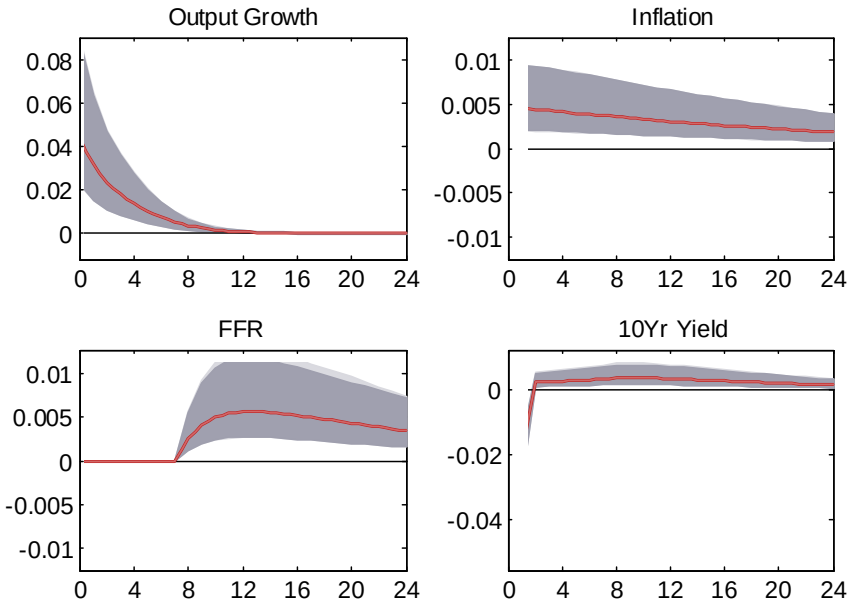
(Duration of Debt is Increased)



Notes: In this simulation, the average duration of debt is 20 quarters, and the purchase operation lasts for 2 quarters, as in the benchmark simulation.The shaded regions show the 90 percent confidence bands. The zero-lower bound operates for 8 quarters.

Figure 8: Effects of Treasury Bond purchases by the Federal Reserve

(Size of Debt is larger)



Notes: In this simulation, the average size of debt is 20% of the GDP, and the purchase operation lasts for 2 quarters, as in the benchmark simulation.The shaded regions show the 90 percent confidence bands. The zero-lower bound operates for 8 quarters.