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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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Economics Working Paper 16113

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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. We use the narrative record to conduct an event study analysis of the operation. To do this, we construct a dataset of weekly-level Treasury holdings of the Federal Reserve in 1932, and the daily term structure of yields obtained from newspaper quotes. The event study indicates that the 1932 program dramatically lowered medium- and long-term Treasury yields; the declines in Treasury Notes and Bonds around the start of the operation were as large as 128 and 42 basis points respectively. A significant proportion of this decline in yields is attributed to the portfolio composition effect. We then use a segmented markets model to analyze the channel through which the open-market purchases affected the economy, namely portfolio rebalancing and signaling effects. Quarterly data from 1920-32 is used to estimate the model with Bayesian methods. 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

How effective are targeted open market purchases in invigorating the economy during a severe downturn? If they have stimulatory effects, can a credible central bank boost their impact by using forward guidance, an unconventional tool of monetary policy? During the financial crisis of 2007-09 in the United States, and the continuing recessionary trends in Europe and Japan, one of the key strategies of central banks has been to purchase specific maturities of government debt. For instance, in the first Quantitative Easing (QE) program, the Federal Reserve purchased $300 billion in long-term Treasury securities, and this purchase program was expanded in the successive QE programs. However, there has been considerable debate about the effect of these purchases on the economy. To examine the impact of the QE purchase programs, the most prominent approach has been to estimate the effect of the programs on the term structure of different types of yields; an expanding literature has examined the effect on Treasury yields[3]. In these analyses, there are two main challenges in estimating the effects of the QE purchases: first, the decline in the state of the economy during the financial 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 this paper, we provide a new perspective on examining our motivating questions above, by comparing the size and effectiveness of the purchase program under QE1 to another policy initiative of the Federal Reserve, undertaken 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 purchase operation between April and August

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

1932, in which it bought $1 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] 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.

We note that 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. 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, and the fact that the 1932 purchase operation was significantly shorter in duration[5], we find that it had large impact effects on the economy. We first

[4] The *New York Times*, quoted in the *Commerical and Financial Chronicle*, April 16, 1932, p. 2774.
[5] The balance sheet of the Federal Reserve was also much smaller.

analyze the effect of the operation on the cross section of Treasury yields using an event study methodology. Since there were no announcements, we construct a narrative record of the period preceding and during the operation. Around the dates identified from the narrative record, there were significant changes in the yields on Treasury securities. For instance, the cumulative effect from the daily changes on Treasury Bills was a decline of 90 basis points (b.p.); Certificates and Notes yields fell by 114 b.p. and the yields on Bonds fell by 42 b.p. Therefore, even though 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.

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. Anecdotal evidence suggests that 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; Perkins, 1999). As we show below, the denomination of Bonds issued may have precluded large sections of households from accessing them[6].

The main hypothesis of the model is that there are two types of financial market participants: the households can hold both long- and short-term Treasury securities; however, they are required to pay a transactions cost to hold the long bonds. The institutional investors, on the other hand, only hold long-term assets, without paying any costs. Since private do-

[6] Additionally, 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%; Banking and Monetary Statistics of the Federal Reserve, 1914-1941, Table 115, pp. 441). 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 (Banking and Monetary Statistics of the Federal Reserve, 1914-1941, Table 125, pp. 464). We thank Gary Richardson for pointing this out.

mestic households had limited access to long-term bonds during the 1920s and 1930s, 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 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. Thus, the open market operation in 1932 was effective in lowering Treasury yields and boosting output growth, even though it lasted less than two quarters. In our counterfactual simulation, we ask the following question: if the Federal Reserve had carried out the operation for a longer duration, and announced the full length of the program, what would the effects be? Our results indicate that the impact on output growth and long-term yields could have been significantly larger. This supports the Friedman and Schwartz (1963) hypothesis that if the Federal Reserve had continued its operation, the continued decline in the economy could have been attenuated much faster. The findings also suggest that since segmentation is substantially lower in modern financial markets, agents are better able to balance their portfolios, 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.

The paper is organized as follows: section 1 contextualizes our analysis in the literature, and the 1932 and QE1 operations are discussed in section 2. Section 3 analyzes the main channels through which asset purchase programs will affect the economy. Narrative evidence and the event study methodology is discussed in section 4. Section 5 presents the model and the results, and section 6 concludes.

1 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 the case of the 1932 operation, no public announcements were made by the Federal Reserve regarding these purchases. Therefore, we construct the narrative record of the period preceding and during the purchase operations from the New York Times. The results of the event study methodology suggest that the 1932 operation had a significant effect on yields, as discussed in section 3 below.

In terms of the channels through which the purchase operation affected yields, we find evidence for both the signaling and portfolio composition channels. The latter has been estimated by Bauer and Rudebusch (2014) for the Federal Reserve's purchase operations during the 2008 financial crisis. The authors find that the purchases lowered future expected short term rates. D'Amico and King (2013) quantify the magnitudes of the scarcity and duration risk channels. McLaren, Banerjee and Latto (2014) also estimate the supply effects of QE, by considering the effects of the Bank of England's announcements on the remaining stock of gilts in the market. In section 3, we discuss the relative importance of the different channels during the 1932 operation.

Some of the institutional background and consequences of the 1932 open market operation for the economy have been explored elsewhere in the literature. 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, Choudhri and Schwartz (2002) 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. However, to our knowledge, this is the first paper to analyze effects of the purchase operation using data on the cross-section of Treasury securities bought by the Federal Reserve (in contrast to a increase in total debt), and the full term structure of daily yields. We also provide estimates of the effects on equities, using corporate bond prices.

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 in the literature. Occhino (2004) develops a model in which households are permanently excluded from the market in government securities, and he 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. The DSGE model in the present paper allows us to estimate the degree of segmentation in the economy, as well as the importance of the signaling versus the portfolio composition channel.

Our analysis of the open market operations in 1932 is conducted in an economic environment with very low policy interest rates. While we focus on the portfolio composition effects of the purchase operation, a number of papers have analyzed the transmission effects of open market operations and other monetary policy actions in economies with low interest rates. Bernanke and Reinhart (2004) present an overview of strategies that can be used to stimulate economic activity when interest rates are very low: managing interest rate expectations, changing the composition of the central bank's securities portfolio and expanding the size of the bank's balance sheet. Grossman and Weiss (1983) use a transactions cost based framework to show that open market purchases of bonds lower nominal and real interest rates and lead to a positive response of prices. In the context of Japan, Auerbach and Obstfeld (2005) show how these bond purchases can generate substantial welfare effects by reducing the real value of public debt, and are able to counter deflationary price paths.

2 Comparing the Institutional Setup of the 1932 Operation and QE1

2.1 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, we first provide evidence to show the remarkable similarities between the economies during the two episodes. 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 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]

2.1.1 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

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

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 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.

[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.

2.1.2 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 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.

[11] Strahan (2012)

[12] Lopez (2009)

The timeline for the first QE program included several important dates, and these have been identified by Gagnon, Raskin, Remache and Sack (2011):

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-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.

2.2 Institutional Comparisons of the 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 implications of the main differences in the institutional setups.

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. We construct a narrative record using reports from the New York Times (section 4) which indicates that financial markets were aware of the program, as well as its potential implications for liquidity in the system and the economy. Hsieh and Romer (2006) also 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.

3 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 signaling 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 medium-term Treasury securities.

3.1 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. (2011) and Bauer and Rudebusch (2014) 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 its 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 change in the Federal Reserve's portfolio during this operation was an increase in the fraction of Note holdings. 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 4.1 below, we use the event-study methodology to examine the effects of changes in the portfolio composition of the Federal Reserve at a daily 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, it 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.

3.2 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 economic conditions to remain weak, and this would lower

[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.

the expectations of future short-term yields. Bauer and Rudebusch (2014) argue that the signaling channel not only affected the expectations of investors about future short term rates, but it also lowered 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 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).

In the absence of overnight swaps and other instruments for the 1932 episode, we use the narrative record presented below, to identify "announcement" effects of the operations on

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

Treasury yields and corporate bond prices.

3.3 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).

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 purchase 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, we hypothesize that any effects of this channel will be difficult to quantify for 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. During the 1932 operation, we observe a cumulative decline in the different Treasury yields, and this yield decline was larger than the fall in yields on corporate bonds.

[15] This is similar to Vayanos and Vila's (2009) preferred habitat model.

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. We use daily 1932 data on corporate bonds below to estimate the strength of the safety channel.

4 Evidence from the Narrative Record and Event Study

To examine the effects of the 1932 operation on changes in yields following the increase in the holdings of the Federal Reserve, we present evidence from the narrative record. These are reports from the New York Times, in the section "Topics in Wall Street: News, Comment and Incidents on the Stock Exchange and In the Financial Markets".

Even before the Federal Reserve began its operations, the media began to note a change in the inclinations of financial markets and the Federal Reserve towards conducting open market operations. On February 17, 1932, the Times reported:

> There is much conjecture in Wall Street whether the Federal Reserve authorities will utilize the excess reserves, to be liberated by the Glass-Steagall bill making United States Government securities eligible as collateral behind Federal Reserve notes, to increase their holdings of "governments."

About two weeks later, on February 28, 1932, the Times noted the willingness of the Federal Reserve to carry out a credit expansion program, which was initiated by a change in the bank rate:

> Now that the Federal Reserve has given unmistakable signs, by the reduction of the New York bank rate of its intentions to relax credit, the chief interest of the financial community is centered upon speculating as to how far the central banking system is likely to go. When the first steps were taken last month, through the reduction of the Reserve's bill-buying rate to levels under the open market, it was the general opinion that the system would follow through with purchases of "governments" as well as a cut in the bank rate. Thus far, the buying of United States Government securities has failed to materialize, although the bank rate reduction has finally been made. Under present conditions, open market buying of government securities appears to be the only effective means whereby the Federal Reserve can pump out credit. Up to now it has been compelled to go slowly in this direction. because of its dwindling supplies of free gold. With the Glass-Steagall bill in effect, however, that handicap at least has been removed.

On March 11, 1932, the first inklings of a purchase operation by the Federal Reserve were observed, and it was considered to be encouraging news for financial markets:

> This week's Federal Reserve statements present some extremely interesting developments, all of which are likely to make pleasant reading for the banking community. The open market operations to expand credit, begun a week ago, were pursued with increased vigor. Holdings of United States Government securities rose $25,168,000 and bill holdings were up $21,944,000.

By April 1, 1932, the increases in the Federal Reserve holdings of government securities were noted to be the highest on record,

> The week's bank report displayed the same trend in evidence since the end of February. Holdings of United States Government securities rose $36,620,000 to $871,618,000, the largest on record.

and on April 8, 1932, the Times reported that

> The weekly Federal Reserve statement shows no let-up in the open-market purchases of government securities [...]. The Reserve System has been adding to its holdings of United States securities at the rate of $25,000,000 a week since the end of February. Member bank discounts increased $2,019,000 and money in circulation rose $19,000,000, two developments which also reflected the first-of-the-month demands. The rise in money in circulation was the first since the week ended on February 3.

Despite the purchases being conducted by the Federal Reserve, there was a growing momentum among financial markets that a larger open market operation was needed, as noted on April 13, 1932:

> The Federal Reserve system has been engaged since the final week in February in an easy-money campaign carried out through the medium of purchases of United States Government securities in the amount of $25,000,000 a week. This policy has already resulted in a marked reduction in member bank borrowings and a relaxation of bank credit so considerable as to cause a drop of 1-1/3% per cent in open market bill rates during the period. The efforts of the Reserve have been greatly aided , however, by the return movement of currency to the banks and by a rise in monetary gold stocks. The second of these factors has now

ceased to operate, and last week, at any rate, the first was inoperative. The question has arisen, accordingly, whether the time is not now ripe for the Federal Reserve to enlarge its campaign by stepping up the rate of weekly purchases of "governments" to say $75,000,000.

On April 14, 1932, the Times noted the rise in projected purchases of the Federal Reserve,

> [T]here was evident in banking circles yesterday marked hopefulness for the outcome of the effort newly undertaken by the Federal Reserve System. The present campaign is evidently to be no half-hearted affair. The Federal Reserve's projected purchases of "governments" at a rate as high as $100,000,000 a week are calculated to pile up surplus reserves in a fashion that will bring tremendous pressure upon the banks to find an outlet for their funds. Moreover, the move comes at a time when commercial bankers everywhere are heartily sick of the recent competitive struggle for liquidity and when the connection between declining bank deposits and falling bank loans and investments has come to be generally recognized.

and on April 15, 1932, the balance sheet of the Federal Reserve was noted to rise to a high record:

> Interest in the weekly bank statement converged upon the single item of United States Government securities which showed a rise of $100,010,000, lifting the system's holdings to a high record at $985,024,000.

While there were concerns about "...whether the banks, under the pressure of mounting excess reserves, can be persuaded to forego their passion for liquidity above all else"[16], the

[16] April 16, 1932, New York Times.

change in loans and investments was considered encouraging. On April 22, 1932, the Times reported:

> Loans and investments, which had been falling sharply, went up $148,000,000, the rise in loans amounting to $64,000,000 and that in investments to $84,000,000.

In the remaining weeks of April 1932, and in early May 1932, the financial markets were reported to fully support the purchase operation. On May 3, 1932, the Times noted:

> The Federal Reserve is engaged in the most determined effort to bring about a rise in the price level ever undertaken by any central bank. It is attempting to do this through controlled, orderly means [...].

On May 20 and May 27, 1932, the Times reported that the Federal Reserve was continuing to follow its "easy money campaign", and that:

> Recent open-market purchases of "governments" have succeeded in building up member bank reserves to a point where they are now about $250,000,000 in excess of requirements. For the future. it is expected, the efforts of the Reserve will be directed toward maintaining this excess of reserves.

Starting in the second week of June 1932, financial markets begin to note the slackening in the Federal Reserve's purchases. For example, the Times reported on June 17, 1932:

> Purchase of "governments" amounted to only $47,640,000, indicating that the Reserve is finding it possible to maintain excess reserves without continuing the heavy pace of open-market operations carried on during the period when these excess reserves were being built up.

On July 19, 1932, the easy-money policy of the Federal Reserve was perceived to be coming to an end:

> The adjournment of Congress has recalled the prediction in some quarters that when this event occurred the Federal Reserve System would terminate its policy of keeping money easy through the purchase of United States Government securities. There are indications that this may prove to be the case. It is generally admitted that it has been rather difficult to persuade bankers outside of large money centres that any great benefit can accrue from such a policy. Since early in April the System has increased its holdings of government securities by $936,000,000, of which $310,444,000 has been bought by the New York Reserve Bank and the remainder by the eleven other regional banks.

By August 13, 1932, the Times reported:

> With gold returning to the country and currency coming back from circulation, there appears to be no further need for continued purchases of United States Government securities by the Federal Reserve Banks.

and on August 19, 1932, the purchase operation was considered to be at an end:

> Open market purchases of United States Government securities by the Federal Reserve Banks, which had been an uninterrupted weekly occurrence since Feb. 24, came to the expected end this week. [...] The current holdings' of $1,851,000,000 are $1,110,000,000 above where they stood when the passage of the Glass Steagall bill gave the signal for the start of the credit expansion program.

The narrative record indicates that even though there were no specific announcement effects, financial markets were aware of the purchase program being conducted. The markets also perceived (to some degree) that the program was being used by the Federal Reserve to deal with deflation.

Given the above discussion, we identify eight dates from the narrative record, regarding the start of the open market operation in 1932: February 17^{th} and 28^{th}, March 11^{th}, April 1^{st}, 8^{th}, 13^{th}, 14^{th} and 15^{th}. The event study methodology below uses these dates to estimate the effects of the operation on the term structure of yields.

4.1 Effects of the 1932 and QE1 Operations: Event Study Methodology

We use the event study methodology to examine the effects of the Federal Reserve operations on the term structure of Treasury yields and corporate bond prices. To our knowledge, the 1932 operation has not been analyzed from this perspective before. We conduct the analysis at a daily frequency. Studies such as Gagnon et al. (2011) 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 from the Federal Reserve. Therefore, to analyze the effects of the operation, we use the dates from the narrative record about the purchase operation.

4.2 Yields and Holdings during the 1932 Operation

For the daily analysis, we construct the series on yields on Treasury bills, notes and certificates and bonds reported in daily newspapers. The first two series are obtained from the Wall Street Journal, and the bonds are taken from the New York Times. One-day changes in these yields around the dates from the narrative record identified above are presented in tables 2, 3 and 4. These changes are the differences between the closing yields reported for the respective securities the trading day before the news report, and the day of the report.

The cumulative decline in Treasury Bills ranges from 20 to 90 basis points[17]. For Treasury Certificates and Notes, the decline in yields ranges from 79 to 114 basis points. In April 1932, the average term left to maturity for these Certificates and Notes is approximately seven months. For Treasury bonds, with an average maturity of approximately 18 years[18], the cumulative decline in yields ranges from 19 to 42 basis points. For all securities, the majority of the changes in yields are concentrated around the April dates.

We also investigate whether there was a change in corporate bond prices around the dates identified from the narrative record. The time series for daily changes in corporate bond prices is constructed for two types of securities: the average of the 40-Bond prices, and the closing prices of railroad bonds. Both these prices are also reported in the Wall Street Journal. The results are shown in table 5. Between April 13 and 16th, cumulative change in the 40-Bond price is an increase in of 2.74 points[19], and railroad bond prices increased by 0.63 points. These changes imply that reports of the Federal Reserve's purchase operation influenced private investment decisions. It is noteworthy that in the initial week of the increase in the Federal Reserve's holdings of Bonds (week of April 20th), the average prices

[17] For the Bills for which a majority of yields were reported in the newspaper.
[18] To the last year of redemption.
[19] If the average maturity of the bonds is 10 years, this would imply a yield decline of 28 b.p.

of the 40-bonds increased by 1.62 points relative to the week before, implying a reduction in the corresponding yields.

The evidence above suggests that both the signaling and portfolio composition channels were operating during the 1932 episode. The reduction in supply of medium term securities to the domestic economy, as the holdings of the Bank increased, lowered yields in successive weeks. For the majority of the Certificates and Notes, the cumulative decline in these yields exceeded the decline in the Bill yields. Similarly, the substantial decline in Bond yields suggest that the signaling channel was operating. The changes in corporate bond prices are indicative of the effects of the portfolio composition channel.

4.3 Yields and Holdings during QE1

Using the announcement dates discussed in section 2.1.2 above, the daily changes in the yields for Bonds and Notes around the events are reported in table 6 from two analyses: Vissing-Jorgensen and Krishnamurthy (2011) and Gagnon et al. (2011). The ten-year bond yields experience the largest cumulative declines around the announcement dates.

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 to a change in the target federal funds rate, and a 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[20]. Thus, the QE1 announcement was distinctly different from the successive announcements in the manner in which it affected financial market expectations.

5 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 are interested in estimating the effects of the purchase operation on the real economy. To do this, we use the medium-scale DSGE model of Smets and Wouters (2007) and Christiano, Eichenbaum and Evans (2005), augmented with the segmented markets features of Andrés, López-Salido, Nelson (2004) and Chen, Cúrdia and Ferrero (2012). In our view, this is a plausible way to model the financial markets of the Depression era since several features of the data suggest significant segmentation in these markets. As shown in table 7, the modal denominations of Liberty Bonds was $1000, which was large relative to per capita income. Goldsmith and Lipsey (1963) construct the asset portfolios for different investors in the economy. Non-farm households held very little debt (short- or long-term), and it was held largely by the Finance sector (table 8). These households also had much smaller holdings of bonds relative to the Finance sector, but they were more heavily invested in stocks. This suggests that a large percentage

[20]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)

of the long-term debt was bought, and held by, wealthy investors. In the model below, these will be modeled using institutional investors.

We augment a New-Keynesian general equilibrium framework with two types of investors: the households who can trade in an unrestricted way in long and short bonds, and the institutional investors, who 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. 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 estimation strategy, we analyze the effects of the purchase operation on the economy.

5.1 Model

5.1.1 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 households can participate in long and short-term bond markets; the institutional investors only buy long-term bonds. Although the investors have identical preferences, a fraction ω_u of households trade in both short and long term government bonds. These are considered to be "unrestricted". They must however pay a transaction cost of ζ_t per unit of the bond purchased (it costs them $1 + \zeta_t$ dollars per unit, instead of 1 dollar). The remaining investors $1 - \omega_u = \omega_r$ only trade in long term bonds but pay no transaction costs (these are "restricted"). Both types of investors 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 investor $i \in \{u, r\}$ 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 i, 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. For example, β_u is the discount factor of the household, and β_r is for the institutional investor.

The budget constraint of the 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 $B_{L,t}^u$ are the price and holdings of the long-term bond respectively, κ is the rate of exponential decay of the long-term bond, W_t^u 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_t^u. The constraint of the 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:

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

where MU_t^u 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:

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

Finally, the pricing equation for the institutional investors is given by:

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

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 in 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.

5.1.2 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.

5.1.3 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 $\rho_m \in (0,1)$.

5.1.4 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 $\phi_T > 0$

5.2 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 Chen, Cúrdia and Ferrero (2012).

5.2.1 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.

5.2.2 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 9.

We obtain mean posterior estimates of market segmentation of 0.76[21]. Table 10 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. Chen, Cúrdia 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

[21] 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.

posterior distribution. However, our estimates of the degree of relative risk aversion are much lower than those estimated for the 2008 crisis (σ_u and σ_r are estimated to be 1.64 and 1.08 relative to 3.35 and 2.08). This would attenuate the responses of consumption and savings to the monetary policy operation. Therefore, we turn to our simulations to estimate the effects of the purchase operation on the economy.

5.3 Simulations

First, we consider the effects of the 1932 purchase on the economy, using the timelines from the actual operation itself. In our benchmark simulation, presented in figure 6, we consider an increase of $1 billion of medium- and long-term Treasury 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 1 and 4.1 above, the Treasury yields were effectively at this bound. Our assumption is that economic agents, on observing the low policy rates and the state of the economy, would not have expected these rates to rise in the immediate future. 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 purchase operation is only assumed to last for two quarters. The Fed is assumed to purchase assets in the first quarter, and it then divests these in the second quarter. Given the unexpected nature of the operation, and no indications that it would continue, we assume that agents 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.

These results are presented in figure 6. The intuition for the effects of the purchase operation operates through the effect of the purchase on the long-term yield on the risk premium ζ; as ζ falls, the institutional investors are not able to arbitrage away the difference between the returns on the long and short term bonds (unlike the households). This affects their expected returns, altering their discount factor and subsequent consumption. As the pricing decisions of intermediate firms and investment decisions of capital goods producers change, consumption and investment are affected in equilibrium.

Our next simulation considers the following counterfactual: 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. That is, it had announced the size and extended duration of the purchase, and agents believed that the perfectly credible central bank would carry out the entire operation. This is similar to the announcement structure followed during the QE1 operation. We find that the real effects are significantly larger: as shown in figure 6, output growth increases by 0.5%, 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 follows 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 signaling channels are important in the transmission of the effects of changes in bond holdings to the real economy[22].

Our next set of simulations considers the effects of lengthening the duration of debt. This

[22] In the fall of 1932 and spring of 1933, there was a spate of banking activity suspensions. Since our estimation period ends in the first quarter of 1932, we do not capture the effects of these suspensions. However, we hypothesize that if the Federal Reserve had continued its purchase operation, the effects of the suspensions may have been attenuated.

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. As the duration of debt is increased, the effect of the risk premium is stronger, and output and inflation responses are magnified and are more persistent. 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 more substantial effects on the economy. For the LSAP program conducted by the Federal Reserve during the crisis of 2008, Chen, Cúrdia and Ferrero (2012) find that the effect on output growth was approximately 0.13%, which is smaller than what the Federal Reserve could have achieved in 1932 if it had used forward guidance and held on to the purchased securities for a longer period.

6 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 and Bond yields around the dates identified from the narrative record. We then estimate the effects of changes in the central bank's asset portfolio composition on the economy. Since there are several indicators which suggest financial market segmentation during the 1920s and 30s, we use a segmented markets approach to model the effects of changes in portfolio composition. Households in the economy are subject to transactions cost while purchasing the long-term bonds, while the institutional investors 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 counterfactual simulation suggests that if the Federal Reserve 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. 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. Also, 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.

Our results from the 1932 open market operation suggest that the Fed in 2008-2009 followed a successful strategy not too dissimilar from what it did over eighty years ago but which it had abandoned too soon. Had the early Fed been more persistent or had it adopted something like forward guidance the Great Contraction would have been attenuated significantly earlier than it did.

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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: Daily Changes in Treasury Bill Yields

Dates from Narrative Record	Issue and Maturity dates of Treasury Bills										
	(I)11/24/31 (M)2/24/32	11/30/31 3/2/32	12/30/31 3/30/32	1/13/32 4/13/32	1/25/32 4/27/32	2/8/32 5/11/32	2/15/32 5/18/32	2/24/32 5/25/32	3/2/32 6/1/32	3/30/32 6/29/32	4/13/32 7/13/32
Feb 17, 1932	0	0	0	0	0	0	0	-	-	-	-
Feb 28, 1932	-	0	-10	-10	-10	-10	-5	-10	-	-	-
Mar 11, 1932	-	-	0	0	0	0	0	0	0	-	-
Apr 1, 1932	-	-	-	-	0	0	0	0	0	-5	-
Apr 8, 1932	-	-	-	-	-10	-10	0	0	0	-10	-
Apr 13, 1932	-	-	-	-	0	-50	-50	-50	-40	-50	-
Apr 14, 1932	-	-	-	-	0	0	0	0	-10	-25	-40
Apr 15, 1932	-	-	-	-	0	0	0	0	0	0	0
Cumulative change	0	0	-10	-10	-20	-70	-55	-60	-50	-90	-40

Note: These are the changes in the level of Treasury Bill yields (in basis points) recorded in the Wall Street Journal, around the dates identified from the narrative record.

Table 3: Daily Changes in Treasury Note Yields

	Maturity dates of Treasury Certificates Notes and Corresponding Rates							
	Cert	Cert	Cert	Cert	Cert	Notes	Cert	Cert
Dates from	Jun15, 1932	Aug1, 1932	Sept15, 1932	Sept15, 1932	Oct15, 1932	Dec15, 1932	Feb1, 1933	Mar15, 1933
Narrative Record	$2\frac{3}{4}\%$	$3\frac{1}{3}\%$	$1\frac{1}{3}\%$	3%	$3\frac{1}{3}\%$	$3\frac{1}{4}\%$	$3\frac{3}{4}\%$	$3\frac{3}{4}\%$
Feb 17, 1932	-30	0	0	0	-	-3	0	-
Feb 28, 1932	-1	1	12	5	-	4	7	-
Mar 11, 1932	-3	-1	-24	-6	-	-5	-7	-
Apr 1, 1932	-6	-13	-6	-8	23	-10	-5	-8
Apr 8, 1932	-24	-24	-13	-17	-26	-14	-30	-29
Apr 13, 1932	-7	-32	-29	-23	-13	-16	-22	-18
Apr 14, 1932	-4	-13	-8	-9	-26	-10	-15	-14
Apr 15, 1932	-13	-29	-31	-27	-47	-25	-42	-35
Cumulative change	-88	-111	-99	-85	-89	-79	-114	-104

Note: These are the changes in the level of Treasury note and Certificate yields (in basis points) recorded in the Wall Street Journal, around the dates identified from the narrative record.

Table 4: Daily Changes in Treasury Bond Yields

Dates from	Maturity dates of Treasury Bonds and Corresponding Rates							
	1947-52	1944-54	1946-56	1943-47	1940-43	1941-43	1946-49	1951-55
Narrative Record	$4\frac{1}{4}\%$	4%	$3\frac{3}{4}\%$	$3\frac{3}{8}\%$	$3\frac{3}{8}\%$	$3\frac{3}{8}\%$	$3\frac{1}{8}\%$	3%
Feb 17, 1932	-3	-3	-2	-3	-3	-6	-2	-2
Feb 28, 1932	0	0	-1	0	1	0	2	-1
Mar 11, 1932	1	-1	0	0	0	0	-1	0
Apr 1, 1932	0	0	-1	-2	0	-1	0	-3
Apr 8, 1932	19	-10	-8	-14	-10	-11	-3	-9
Apr 13, 1932	-2	-2	-7	-5	-13	-11	-6	-5
Apr 14, 1932	-6	-7	-6	-23	-20	-21	-23	-21
Apr 15, 1932	0	4	0	9	8	8	4	12
Cumulative change	9	-19	-25	-38	-37	-42	-29	-29

Note: These are the changes in the level of Treasury note yields (in basis points) recorded in the New York Times, around the dates identified from the narrative record.

Table 5: Daily Changes in Dow Jones Bond Prices

	Levels of Bond Prices	
Dates from Narrative Record	40 Bonds (Avg)	Railroad Bonds (Close)
Feb 17, 1932	79.17	38.81
Feb 28, 1932	79.96	36.29
Mar 11, 1932	82.21	36.10
Apr 1, 1932	77.69	28.53
Apr 8, 1932	74.45	23.44
Apr 13, 1932	73.34	20.94
Apr 14, 1932	73.45	22.15
Apr 15, 1932	74.69	22.95

Note: These are the levels of bond prices recorded in the Wall Street Journal, around the dates identified from the narrative record.

Table 6: Response of Yields around the QE1 Announcement Dates

Announcement Dates	Changes in yields on 10-year Bonds (in b.p.)		5-year Notes	1-year Notes
	K-V	GRRS	K-V	K-V
November 25, 2008	-36	-22	-23	-2
December 1, 2008	-25	-19	-28	-13
December 16, 2008	-33	-26	-15	-5
January 28, 2009	28	14	28	4
March 18, 2009	-41	-47	-36	-9
Cumulative change	-107	-104	-74	-25

Note: These estimates are taken from Vissing-Jorgensen and Krishnamurthy (2011; noted as K-V) and Gagnon et al. (2010).

Table 7: Denominations of Liberty Bonds

Denominations on June 20, 1920	Denominations in 2009$	% of All Bonds Outstanding
$50	536.34	7.87
100	1072.69	12.11
500	5363.43	9.33
1000	10,726.85	41.49
5000	53,634.25	7.23
10,000	107,268.50	16.10
50,000	536,342.50	1.32
100,000	1,072,685.00	4.54

Note: These are taken from Kang and Rockoff (2015).

Table 8: Asset Compositions

	Non-farm households	Finance
	(% of total assets in 1945)	
Financial assets	**67.9**	**99.3**
Bonds	13.0	58.6
Stocks	17.9	2.1
Debt	**4.9**	**93.9**
Short-term	1.9	72.9
Long-term	3.0	21.0

Note: These are obtained from the National Balance Sheet of the United States, Goldsmith and Lipsey (1963)

Table 9: Estimates from the Prior Distribution

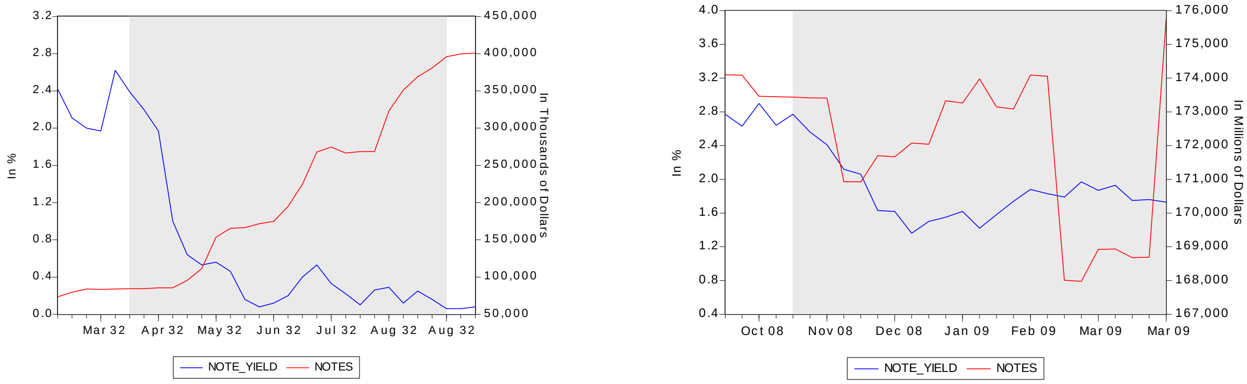
Coeff	Dist	5%	Median	95%	Coeff	Dist	5%	Median	95%
400γ	G	0.3416	0.9180	1.9384	χ_{wu}	B	0.2486	0.6143	0.9024
400π	G	0.3416	0.9180	1.9384	ν	G	1.2545	1.9585	2.8871
$400(\beta_u^{-1}-1)$	G	0.6272	0.9792	1.4436	ζ_w	B	0.3351	0.5000	0.6649
400ζ	G	0.2558	0.5657	1.0614	ζ_p	B	0.3351	0.5000	0.6649
B^{LMV}/B	G	0.6953	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 10: 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

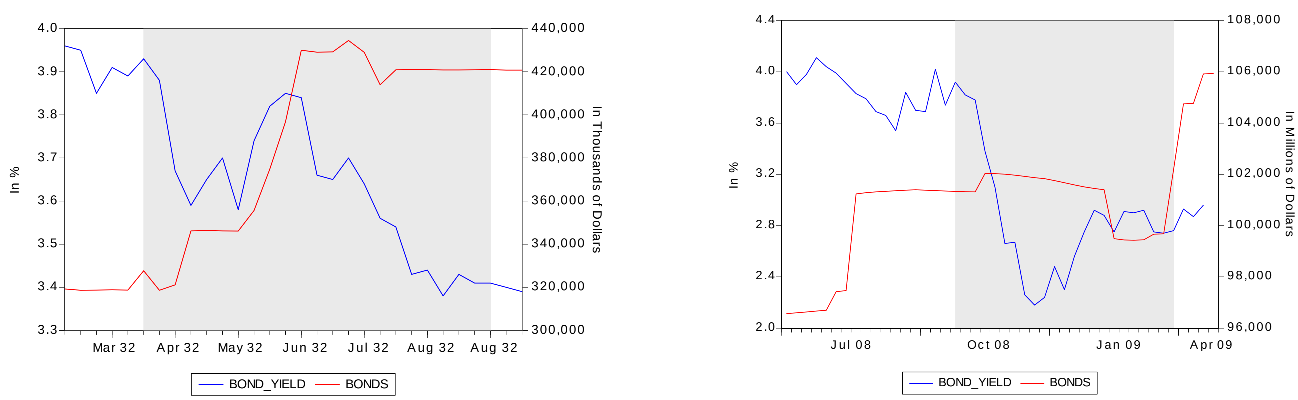
1932 QE1



Notes: This figure shows the weekly yields on Treasury notes during the 1932 and 2008-09 operations (on the left axis), and the holdings of these securities by the Federal Reserve. The shaded regions show the period of the operations.

Figure 2: US Treasury Bonds and Yields

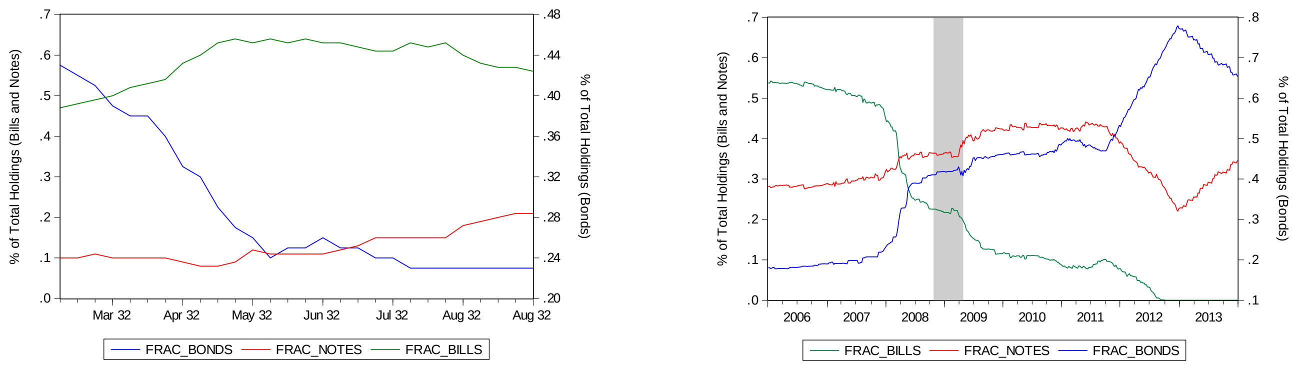
1932 QE1



Notes: This figure shows the weekly yields on Treasury bonds during the 1932 and 2008-09 operations (on the left axis), and the holdings of these securities by the Federal Reserve. The shaded regions show the period of the operations.

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

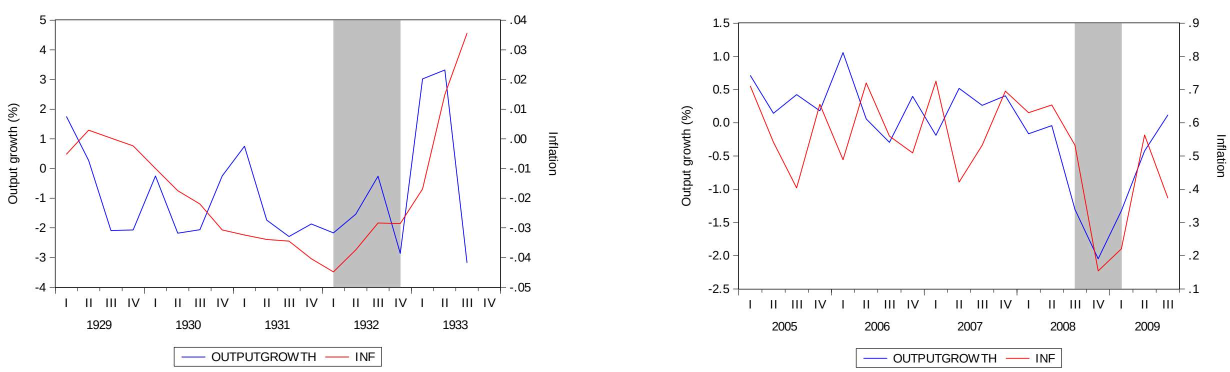
1932 QE1



Notes: This shows the Federal Reserve's holdings of Treasury Bills, Bonds and Notes as a fraction of the total holdings, during the 1932 and 2008-09 operations. The percentage holdings of Bonds are shown on the right axis. The shaded regions show the period of the operations.

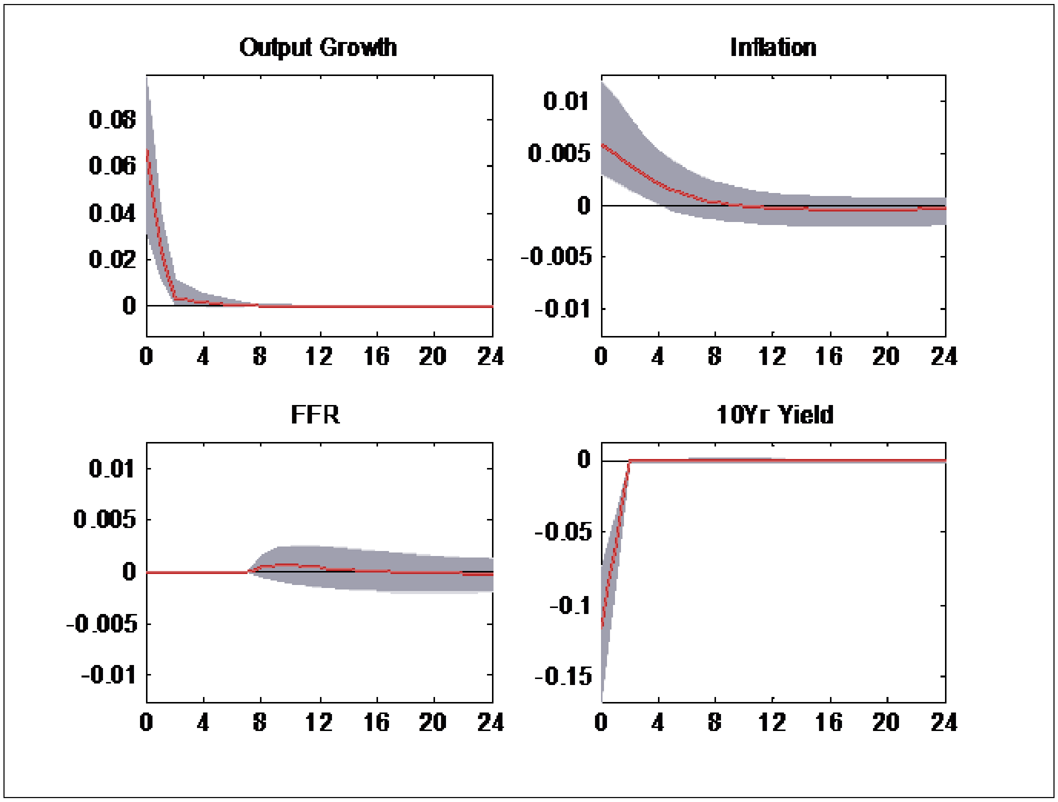
Figure 4: Output growth and Inflation

1932 QE1



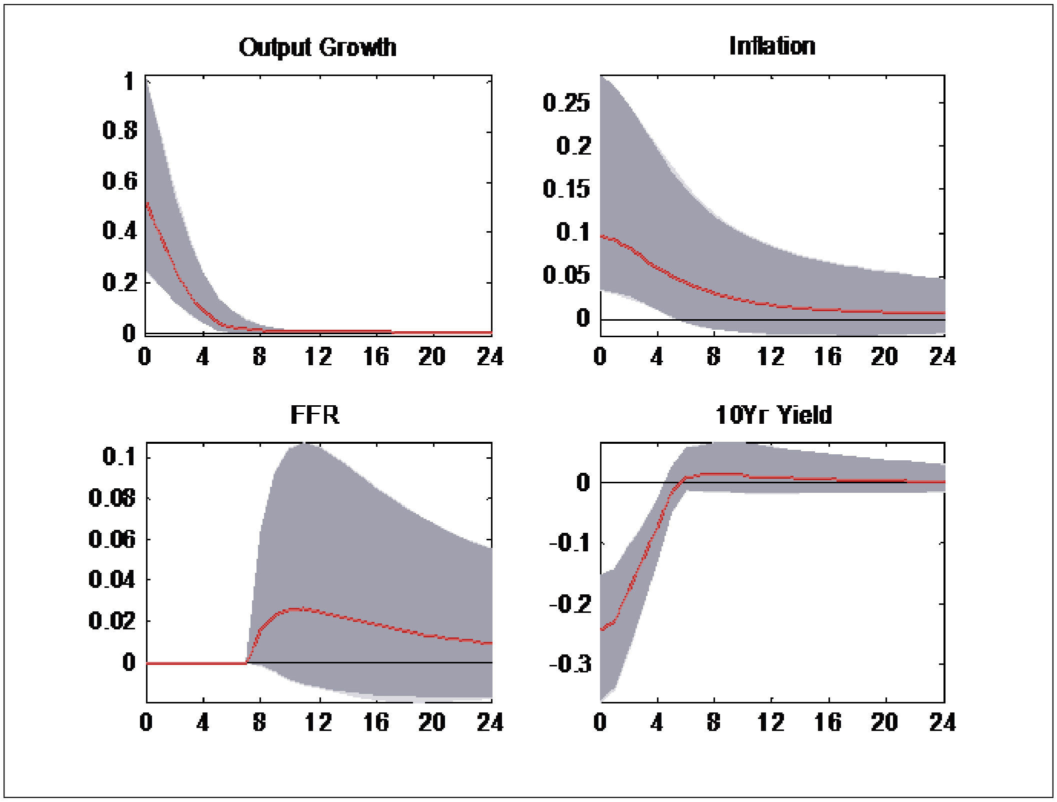
Notes: This shows the evolution of output growth and inflation in the years preceding and following the purchase operations.

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



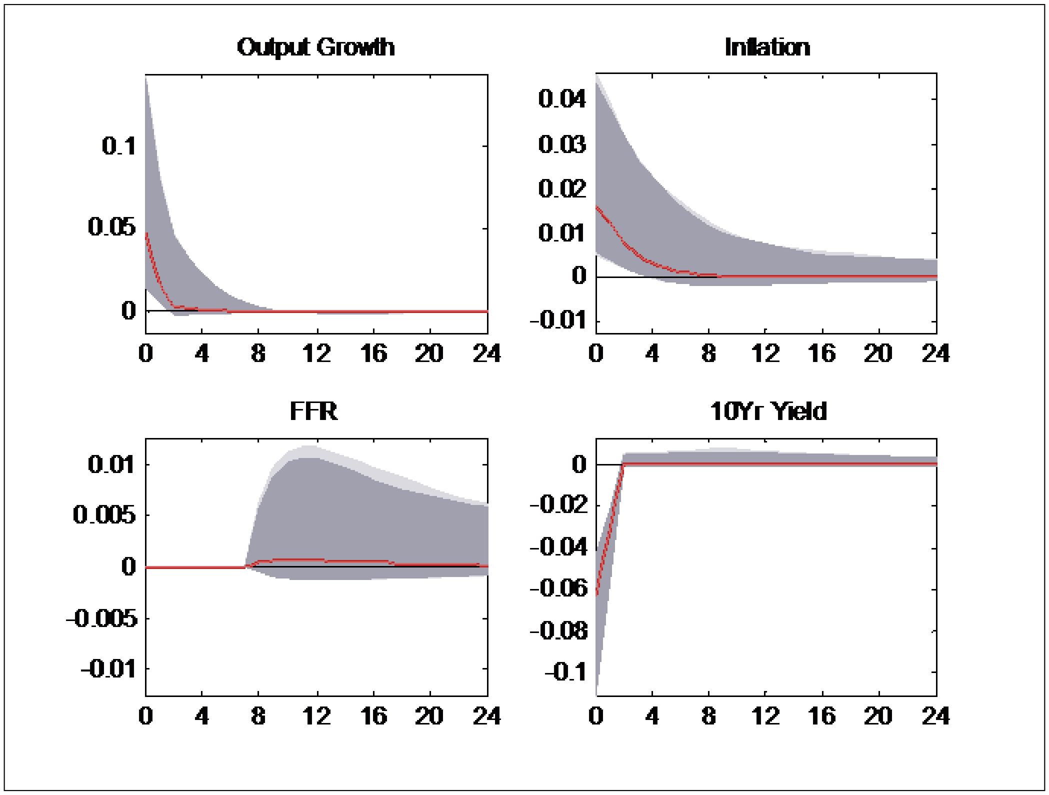
Notes: In this simulation, the average duration of debt is 15 quarters, and the purchase operation lasts for one quarter. The Fed then divests its holdings over the next quarter. The shaded regions show the 90 percent confidence bands. The zero-lower bound operates for 8 quarters.

Figure 6: Effects of Treasury Bond purchases by the Federal Reserve
(Long-term securites are not immediately divested)



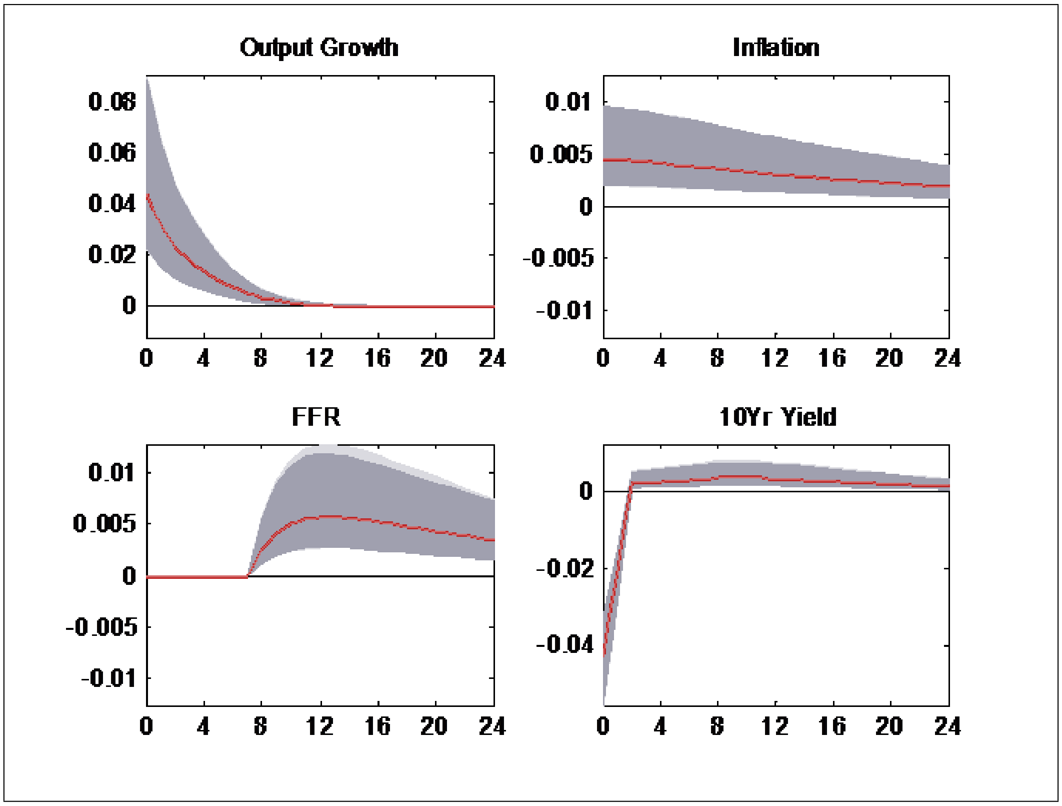
Notes: In this simulation, the average duration of debt is 15 quarters, and the purchase operation lasts for two quarters. The Fed holds onto the long-term assets for two quarters, and then divests these over the next two quarters. The shaded regions show the 90 percent confidence bands. The zero-lower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

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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Appendix: For Online Publication

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1 Introduction

This appendix describes the components of the DSGE framework used in the paper. It is based on the medium-scale DSGE model of Smets and Wouters (2007) and Christiano, Eichenbaum and Evans (2005), with the segmented markets features of Andrés, López-Salido, Nelson (2004) and Chen, Cúrdia and Ferrero (2012). Data used in the estimation are also described here.

2 Model

2.1 Households

There is a continuum of investors of measure one. Two types of investors, $j = u, r$ consume C_t^j and dislike labor L_t^j. Consumption is relative to productivity Z_t. The utility function over the infinite horizon is given by

$$E_t \sum_{s=0}^{\infty} \beta_j^s b_{t+s}^j \left[\frac{1}{1-\sigma_j} \left(\frac{C_{t+s}^j}{Z_{t+s}} - h \frac{C_{t+s-1}^j}{Z_{t+s-1}} \right)^{1-\sigma_j} - \frac{\varphi_{t+s}^j \left(L_{t+s}^j (i) \right)^{1+\nu}}{1+\nu} \right] \tag{1}$$

where β_j is the discount factor, b^j is the preference shock, σ_j is the CRRA, h is the habit parameter and φ^j is the labor supply shock of household j.

There are two types of bonds. The one-period bonds B_t pay a nominal return of R_t at time $t+1$. Long term bonds are perpetuities that cost $P_{L,t}$ at time t and pay an exponentially decaying coupon κ^s at time $t+s+1$. Although the investors have identical preferences, a fraction ω_u of households trade in both short and long term government bonds. These are considered to be "unrestricted". They must however pay a transaction cost of ζ_t per unit of the bond purchased (it costs them $1+\zeta_t$ dollars per unit, instead of 1 dollar). The remaining investors $1-\omega_u = \omega_r$ only trade in long term bonds but pay no transaction costs (these are "restricted"). For the long-term bond, the price $P_{L,t} = 1/\left(R_{L,t} - \kappa\right)$, where $R_{L,t}$ is the gross yield on the bond. The bond duration is $R_{L,t}/\left(R_{L,t}-\kappa\right)$.

For the households, the flow budget constraint (FBC) is:

$$P_tC_t^u+B_t^u+\left(1+\zeta_t\right)P_{L,t}B_{L,t}^u\leq R_{t-1}B_{t-1}+\sum_{s=1}^{\infty}\kappa^{s-1}B_{L,t-s}^u+W_t^u\left(i\right)L_t^u\left(i\right)+\mathcal{P}_t+\mathcal{P}_t^{cp}+\mathcal{P}_t^{fi}-T_t^u. \tag{2}$$

Here $\mathcal{P}_t^{fi}$ are the per-capita nominal profits of the financial intermediary (who receives the transactions cost and distributes to the profits to all shareholders). $\mathcal{P}_t$ and $\mathcal{P}_t^{cp}$ are the profits from the ownership of intermediate goods produces and capital producers respectively. T_t^u are lump-sum taxes.

The FBC of the institutional investors is:

$$P_tC_t^r+P_{L,t}B_{L,t}^r\leq\sum_{s=1}^{\infty}\kappa^{s-1}B_{L,t-s}^r+W_t^r\left(i\right)L_t^r\left(i\right)+\mathcal{P}_t+\mathcal{P}_t^{cp}+\mathcal{P}_t^{fi}-T_t^r. \tag{3}$$

In the above expressions, the price of the final good is P_t, $W_t^j\left(i\right)$ is the wage of a household of type j. From the unrestricted households' optimization, FOC for short bonds is:

$$\Xi_t^u=\beta_uR_tE_t\left(\Xi_{t+1}^u\right), \tag{4}$$

and for the long bonds is:

$$\frac{1+\zeta_t}{R_{L,t}-\kappa}\Xi_t^u=\beta_uE_t\left(\frac{R_{L,t+1}}{R_{L,t+1}-\kappa}\Xi_{t+1}^u\right). \tag{5}$$

Here Ξ_t^u is the Lagrange multiplier associated with the household's budget constraint.

The instutional investors only hold long bonds, and for these, the FOC is:

$$\frac{1}{R_{L,t}-\kappa}\Xi_t^r=\beta_rE_t\left(\frac{R_{L,t+1}}{R_{L,t+1}-\kappa}\Xi_{t+1}^r\right), \tag{6}$$

and Ξ_t^r is the Lagrange multiplier associated with the institutional investor's budget constraint.[3]

Both types of investors set their wages on a Calvo staggered basis (wages are reset with probability $1-\zeta_w$), and this decision is based on the demand for their specific labor input

[3]Here the Lagrangian multiplier of investors of type i, $\Xi_t^{u,p}\left(i\right)$, is normalized to $\Xi_t^u=\Xi_t^{u,p}\left(i\right)Z_tP_t\forall i$.

$L_t(i)$. This is supplied to perfectly competitive labor agents, which aggregate the labor inputs into L_t :

$$L_t = \left[\int_0^1 L_i(i)^{\frac{1}{1+\lambda_w}} di\right]^{1+\lambda_w}, \tag{7}$$

where $\lambda_w > 0$ is the steady state wage markup. This implies the FOC for the demand of the labor input is:

$$L_t(i) = \left(\frac{W_t(i)}{W_t}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t \tag{8}$$

and the aggregate wage is

$$W_t = \left[\int_0^1 W_i(i)^{-\frac{1}{\lambda_w}} di\right]^{-\lambda_w}. \tag{9}$$

Then the labor supply decision of the household is:

$$\min_{\tilde{W}_t^u(i)} E_t \sum_{s=0}^{\infty} (\zeta_w \beta_u)^s b_{t+s}^u \frac{\varphi_{t+s}^u}{1+\nu_u} L_{t+s}^u(i)^{1+\nu_u}$$

subject to the demand for labor, FBC in (2) and wage updating given by $W_{t+s}^u(i) = (\Pi e^{\gamma})^s \tilde{W}_t^u(i)$. The first order conditions imply that the aggregate wage index can be rewritten as:

$$W_t = \left\{(1-\zeta_w)\left[\omega_u\left(\tilde{W}_t^u\right)^{\frac{-1}{\lambda_w}} + \omega_r\left(\tilde{W}_t^r\right)^{\frac{-1}{\lambda_w}}\right] + \zeta_w\left(\Pi e_t^{\gamma} W_{t-1}\right)^{\frac{-1}{\lambda_w}}\right\}^{-\lambda_w}. \tag{10}$$

Wage setting: Households are monopolistic suppliers of differentiated labor inputs and set wages using Calvo. The fraction of households which do not re-set their wages index it to the steady state rate of inflation and productivity growth.

2.2 Final goods producers

The final good Y_t is made up of a composite of goods:

$$Y_t = \left[\int_0^1 Y_t(i)^{1/\left(1+\lambda_f\right)} di\right]^{\left(1+\lambda_f\right)}. \tag{11}$$

These final good producers buy intermediate goods, package them into Y_t, and sell the final good to consumers, investors and the government. Their maximization problem (in a perfectly competitive market) is:

$$\max_{Y_t, Y_t(i)} P_t Y_t - \int_0^1 P_t(i) Y_t(i) \, di \tag{12}$$

subject to the constraint $Y_t = \left[\int_0^1 Y_t(i)^{1/\left(1+\lambda_f\right)} di\right]^{\left(1+\lambda_f\right)} \mu_{f,t}$. The FOCs imply:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\left(1+\lambda_f\right)}{\lambda_f}} Y_t \tag{13}$$

and $P_t = \left[\int_0^1 P_t(i)^{-1/\lambda_f} di\right]^{-\lambda_f}$.[4] Since the marginal cost is the same for all firms[5], profits can be rewritten as $\left[P_t(i) - \lambda_{f,t} MC_t\right] Y_t(i)$, where $\lambda_{f,t}$ is the time-varying markup on prices, and evolves as:

$$\ln \lambda_{f,t} = \rho_{\lambda_f} \ln \lambda_{f,t-1} + \varepsilon_{\lambda,t}, \varepsilon_{\lambda,t} \sim N\left(0, \sigma^2_{\varepsilon_\lambda}\right). \tag{14}$$

With Calvo pricing, where each firm readjusts its prices with probability $1 - \zeta_p$ in each period, and those that do not, increase their prices $P_t(i)$ at the steady state rate of inflation π[6]. The optimization problem for the firms that can adjust their prices is to choose a price level $\tilde{P}_t(i)$ to maximize expected discounted profits subject to the constraint $Y_{t+s}(i) = \left[\frac{\tilde{P}_t(i)\Pi^s}{P_{t+s}}\right]^{-\frac{1+\lambda_f}{\lambda_f}} Y_{t+s}$, where $\Pi = 1 + \pi$. From the resulting FOC and the fact that all firms that readjust their prices face the same optimization problem, the price[7] is:

$$P_t = \left[\left(1 - \zeta_p\right) \tilde{P}_t^{-1/\lambda_f} + \zeta_p \left(\Pi P_{t-1}\right)^{-1/\lambda_f}\right]^{-\lambda_f}. \tag{15}$$

[4] λ_f is constrained to lie between $(0, \infty)$.

[5] $MC_t = \left[W_t + R_t^k \frac{K_t(i)}{L_t(i)}\right] Z_t^{-(1-\alpha)} \left(\frac{K_t(i)}{L_t(i)}\right)^{-\alpha}$

[6] The rate of inflation is $\pi_t = P_t / P_{t-1}$.

[7] Here the i subscript has been dropped.

2.3 Intermediate goods producers

Intermediate good's producer i uses the technology:

$$Y_t(i) = Z_t^{1-\alpha} K_t(i)^{\alpha} L_t(i)^{1-\alpha}, \tag{16}$$

where $K_t(i)$ is the capital used in production and $L_t(i)$ is a composite labor input. Z_t is the total factor productivity, and $z_t = \log\left(\frac{Z_t/Z_{t-1}}{1+\gamma}\right)$ follows the process:

$$z_t = \rho_z z_{t-1} + \varepsilon_{z,t}, \varepsilon_z \sim N\left(0, \sigma_z^2\right). \tag{17}$$

The profit of the firm is given by $P_t(i) Y_t(i) - W_t L_t(i) - R_t^k K_t(i)$, where W_t is the aggregate nominal wage rate and R_t^k is the rental rate of capital. Combining the cost minimization FOCs yields:

$$K_t = \frac{\alpha}{1-\alpha} \frac{W_t}{R_t^k} L_t. \tag{18}$$

2.4 Capital producers

All the households own a representative perfectly competitive firm which invests in capital, chooses utilization rate and rents the capital to intermediate firms. The utilization rate is u_t, and each period, an "effective" amount of capital is rented out:

$$K_t = u_t \bar{K}_{t-1}. \tag{19}$$

This utilization subtracts real resources, measured in terms of the consumption good: $a(u_t)\bar{K}_{t-1}$. Capital's law of motion is:

$$\bar{K}_t = (1-\delta)\bar{K}_{t-1} + \mu_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t. \tag{20}$$

Here $\delta \in (0,1)$ is the depreciation rate, S is the cost of adjusting investment. $S' > 0$ and $S" > 0$. The capital producers maximize the expected discounted stream of dividends to their shareholders, subject to the constraint in 20.

2.5 Government

The flow budget constraint of the government is:

$$B_t + P_{L,t}B_{L,t} = R_{t-1}B_{t-1} + (1 + \kappa P_{L,t})\,B_{L,t-1} + P_tG_t - T_t, \tag{21}$$

where the LHS is the nominal market value of the total debt issued by the government. The RHS is the cost of servicing bonds maturing at t along with government spending G_t and taxes T_t.

The composition of debt is controlled by the government as:

$$\frac{P_{L,t}B_{L,t}}{P_tZ_t} = S\left(\frac{P_{L,t-1}B_{L,t-1}}{P_{t-1}Z_{t-1}}\right)^{\rho_B} e^{\varepsilon_{B,t}}, \tag{22}$$

where $\varepsilon_{B,t}$ is an exogenous i.i.d. shock and $\rho_B \in (0,1)$. S is a constant required to make the debt equation above an identity at steady state. The LSAP program will be interpreted as the shock to the composition of outstanding government liabilities relative to the past average.

The primary surplus of the government will evolve as:

$$\frac{T_t}{P_tZ_t} - \frac{G_t}{Z_t} \equiv \Phi_{z,t} = \Phi\left(\frac{P_{L,t-1}B_{LZ,t-1} + B_{Z,t-1}}{P_tB_{LZ,t} + B_{Z,t}}\right)^{\phi_T} e^{\varepsilon_{T,t}}, \tag{23}$$

where $\phi_T > 0$, $\varepsilon_{T,t}$ follows the stationary AR(1) process, $B_{Z,t} \equiv B_t/P_tZ_t$ and $B_{LZ,t} \equiv B_{L,t}/P_tZ_t$

2.6 Central Bank

In periods when the zero-lower bound is not binding, the Taylor rule (Taylor, 1993) with interest rate smoothing is followed:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_m}\left[\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\left(\frac{Y_t}{e^{4\gamma}Y_{t-1}}\right)^{\phi_y}\right]^{1-\rho_m} e^{\varepsilon_{m,t}}, \tag{24}$$

where $\varepsilon_{m,t}$ is an i.i.d. shock, and $\rho_m \in (0,1)$, $\phi_\pi > 1$ and $\phi_y \geq 0$.

2.7 Intuition for the effect of LSAP

The baseline formulation of Cúrdia, Chen and Ferrero (2012) for the transaction cost is:

$$\zeta_t = \left(\frac{P_{L,t}B_{L,t}}{P_t Z_t}\right)\exp\left(\varepsilon_{\zeta,t}\right). \tag{25}$$

The authors use the Euler equations of the households and institutional investors to show:

$$E_t\left\{\frac{\Xi_{t+1}^{p,u}}{\Xi_t^{p,u}}\left[\frac{P_{L,t+1}}{\left(1+\zeta_t\right)P_{L,t}}R_{L,t+1} - \frac{P_{L,t+1}^{EH}}{P_{L,t}^{EH}}R_{L,t+1}^{EH}\right]\right\} = 0. \tag{26}$$

Here, $P_{L,t+1}^{EH}$ and $R_{L,t+1}^{EH}$ are the price and yield to maturity of the long-term bond in the absence of transactions costs, while holding the path for the marginal utility of consumption constant. Under the first order approximation, the risk premium is defined as the difference between the yields to maturity with and without transactions costs:

$$\widehat{RP}_t \equiv \hat{R}_{L,t} - \hat{R}_{L,t}^{EH}, \tag{27}$$

and combining the approximations of the no-arbitrage condition and the relation between the price and yields, the authors obtain:

$$\widehat{RP}_t = \frac{1}{D_L}\sum_{s=0}^{\infty}\left(\frac{D_L-1}{D_L}\right)^s E_t\zeta_{t+s}. \tag{28}$$

2.8 Resource Constraints and Exogenous Processes

Budget constraint (BC) for the household is:

$$P_tC_t^u + B_t^u + \left(1+\zeta_t\right)P_{L,t}B_{L,t}^u = R_{t-1}B_{t-1}^u + \frac{R_{L,t}}{R_{L,t}-\kappa}B_{L,t-1}^u + \int W_t^u\left(i\right)L_t^u\left(i\right) + \mathcal{P}_t + \mathcal{P}_t^{cp} + \mathcal{P}_t^{fi} - T_t^u, \tag{29}$$

and for the institutional investor is:

$$P_tC_t^r + P_{L,t}B_{L,t}^r \leq \frac{R_{L,t}}{R_{L,t}-\kappa}B_{L,t-1}^r + \int W_t^r\left(i\right)L_t^r\left(i\right) + \mathcal{P}_t + \mathcal{P}_t^{cp} + \mathcal{P}_t^{fi} - T_t^r. \tag{30}$$

The Government's BC is:

$$B_t + \frac{B_{L,t}}{R_{L,t} - \kappa} = R_{t-1} B_{t-1} + \frac{R_{L,t}}{R_{L,t} - \kappa} B_{L,t-1} + P_t G_t - R_t. \tag{31}$$

Since

$$\mathcal{P} = \int_t \mathcal{P}(i)\, di = \int P_t(i)\, Y_t(i)\, di - W_t L_t - R_t^K K_t, \tag{32}$$

it is the case that

$$\begin{aligned} W_t L_t &= \int W_t^u(i)\, L_t^u(i)\, di + \int W_t^r(i)\, L_t^r(i)\, di \\ P_t Y_t &= \int P_t(i)\, Y_t(i)\, di. \end{aligned} \tag{33}$$

The profits of the capital producers and financial institution are

$$R_t^K K_t - P_t a(u_t)\, \bar{K}_{t-1} - P_t I_t$$

$$\mathcal{P}^{fi} = \omega_u \frac{\zeta_t}{R_{L,t} - \kappa} B_{L,t}^u. \tag{34}$$

The budget constraint is:

$$\omega_u C_t^u + \omega_r C_t^r + G_t + a(u_t)\, \bar{K}_{t-1} + I_t = Y_t. \tag{35}$$

The exogenous processes are specified as:

$$\begin{aligned} \text{Technology} &: \quad z_t = \ln\left(e^{-\gamma} Z_t / Z_{t-1}\right) \\ z_t &= \rho_z z_{t-1} + \varepsilon_{z,t} \end{aligned}$$

$$\text{Preference for leisure: } \ln \varphi_t = \rho_\varphi \ln \varphi_{t-1} + \varepsilon_{\varphi,t}$$

$$\text{Price mark up: } \ln \lambda_{f,t} = \varepsilon_{\lambda,t}.$$

$$\text{Capital adjustment cost process: } \ln \mu_t = \rho_\mu \ln \mu_{t-1} + \varepsilon_{\mu,t}$$

$$\text{Intertemporal preference shifter: } \ln b_t = \rho_b \ln b_{t-1} + \varepsilon_{b,t}$$

$$\text{Government spending: } \ln g_t = \rho_g \ln g_{t-1} + \varepsilon_{g,t}$$

$$\text{Exogenous risk premium shock: } \varepsilon_{\zeta,t} = \rho_\zeta \varepsilon_{\zeta,t-1} + \epsilon_{\zeta,t}$$

The remaining shocks are the monetary policy shock ($\varepsilon_{m,t}$), fiscal shock ($\varepsilon_{T,t}$) and the long-term bond supply shock ($\varepsilon_{B,t}$).

3 Model Steady State

In steady state, the log of productivity grows at the rate γ and constant inflation is Π. Following Christiano et al. (2011), $a(u_t)$ is such that $u = 1$ in SS, and $a(1) = 0$. Also, $Y/Z = 1$, $\nu_u = \nu_r = \nu$, $S(e^\gamma) = S'(e^\gamma) = 0$. The ratio of the consumption and Lagrange multipliers associated with the maximization problems of the households and institutional investors are estimated. The levels of b^u and b^r are allowed to take whichever value required to allow the ratios to be consistent with each other and the resource constraints.

From the Euler equations:

$$1 = \beta_u R\, e^{-\gamma}\Pi^{-1}, \tag{36}$$

$$(1+\zeta) = \frac{R_L}{R}, \tag{37}$$

$$\beta_u = \beta_r (1+\zeta). \tag{38}$$

The level of long debt is determined by the risk premium:

$$B^{LMV}/Z = \zeta^{-1}(\zeta), \tag{39}$$

and taxes are determined by the government BC:

$$\frac{T}{Z} = \frac{G}{Z} - \left(1-\beta_u^{-1}\right)\frac{B}{Z} - \left(\frac{1}{R_L-\kappa} - \frac{R_L}{R_L-\kappa}\frac{1}{e^\gamma\Pi}\right)\frac{B_L}{Z}. \tag{40}$$

The unit marginal efficiency of investment shock implies $q = 1$, and unit utilization implies $r^k = a'(1)$, which determines $a'(1)$ given r^k. The FOC for investment implies:

$$r^k = \bar{\beta}^{-1} e^\gamma - (1-\delta). \tag{41}$$

Here

$$\bar{\beta} = \frac{\omega_u \beta_u \frac{\Xi^u}{\Xi^r} + \omega_r \beta_r}{\omega_u \frac{\Xi^u}{\Xi^r} + \omega_r}, \tag{42}$$

where Ξ^u/Ξ^r are derived from the Euler equations of the households (Ξ^u) and investors (Ξ^r).

Price setting implies that the marginal cost $mc = \frac{1}{1+\lambda_f}$, and the definition of marginal cost implies $w_z = \tilde{w}_z \left(r^k\right)^{\frac{\alpha}{1-\alpha}}$, where $\tilde{w}_z = (1+\lambda_f)^{-\frac{1}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} (1-\alpha)$.

The technology function $L = \left(\frac{K}{Z}\right)^{\frac{\alpha}{1-\alpha}}$ and the capital demand implies that $L = \tilde{L} \left(r^k\right)^{\frac{\alpha}{1-\alpha}}$, where $\tilde{L} \equiv \left(\frac{\alpha}{1+\lambda_f}\right)^{\frac{-\alpha}{1-\alpha}}$. The other relationships are:

$$\text{Effective capital: } \frac{\overline{K}}{Z} = e^{\gamma} \left(\frac{\alpha}{1+\lambda_f}\right) \left(r^k\right)^{-1} \tag{43}$$

$$\text{Investment: } \frac{I}{Z} = [e^{\gamma} - (1-\delta)] \left(\frac{\alpha}{1+\lambda_f}\right) \left(r^k\right)^{-1} \tag{44}$$

$$\text{Resource constrain: } \omega_u \frac{C^u}{Z} + \omega_r \frac{C^r}{Z} = 1 - \frac{I}{Z} - \frac{G}{Z}. \tag{45}$$

The log-linear approximations of these relations are available upon request.

4 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. Following

Cúrdia, Chen and Ferrero (2012), the mapping of these variables to the states is:

$$
\begin{aligned}
\Delta Y_t^{obs} &= 100\left(\gamma + \hat{Y}_{z,t} - \hat{Y}_{z,t-1} + \hat{z}_t\right) \\
L_t^{obs} &= 100\left(L + \hat{L}_t\right) \\
\Delta w_t^{obs} &= 100\left(\gamma + \hat{w}_{z,t} - \hat{w}_{z,t-1} + \hat{z}_t\right) \\
\pi_t^{obs} &= 100\left(\pi + \hat{\pi}_t\right) \\
r_t^{obs} &= 100\left(r + \hat{r}_t\right) \\
r_{L,t}^{obs} &= 100\left(r_L + \hat{r}_{L,t}\right) \\
B_t^{ratio,obs} &= \frac{P_L B_{L,z}}{B_z}\left(1 + \hat{P}_{L,t} + \hat{B}_{L,z,t} - \hat{B}_{z,t}\right)
\end{aligned}
$$

where the state variables are in deviations from steady state values, $X_z = X/Z$ for variable X, and $\pi = \ln \Pi$, $r = \ln R$ and $r_L = \ln R_L$. The observable ΔY_t^{obs} corresponds to the first difference in logs of the real GDP series. Δw_t^{obs} is the first difference in logs of the real wage series, multiplied by 100.

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