The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy*

Arvind Krishnamurthy[1] *and Annette Vissing-Jorgensen*[2]

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Abstract: We evaluate the effect of the Federal Reserve's purchase of long-term Treasuries and other long-term bonds ("QE1" in 2008-2009 and "QE2" in 2010-2011) on interest rates. Using an event-study methodology that exploits both daily and intra-day data, we find a large and significant drop in nominal interest rates on medium and long-term safe assets (Treasuries, Agency bonds, and highly-rated corporate bonds). There are several channels at work. First, the signaling channel significantly lowers the yields on intermediate maturity bonds. Second, yields on long maturity safe bonds fall because there is a unique clientele for medium and long-term safe nominal assets, and the Fed purchases reduce the supply of such assets and hence increase the equilibrium safety-premium. For QE1 we find smaller effects on nominal (default-adjusted) interest rates on less safe assets such as Baa corporate rates. The impact of quantitative easing on MBS rates is large when QE involves MBS purchases, but not when it involves Treasury purchases, indicating that another main channel for QE is to affect the equilibrium price of mortgage-specific risk. Evidence from inflation swap rates and TIPS show that expected inflation increased due to both QE1 and QE2, implying that reductions in real rates were larger than reductions in nominal rates. Our analysis implies that (a) it is inappropriate to focus only on Treasury rates as a policy target because QE works through several channels that affect particular assets differently, and (b) effects on particular assets depend critically on which assets are purchased.

[1] Kellogg School of Management, Northwestern University and NBER

[2] Kellogg School of Management, Northwestern University, NBER and CEPR

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1. Introduction

The Federal Reserve has recently pursued the unconventional policy of purchasing large quantities of long-term securities, including Treasuries, Agency bonds, and Agency Mortgage Backed Securities (quantitative easing, or "QE"). The stated objective of quantitative easing is to reduce long-term interest rates in order to spur economic activity.[3] There is significant evidence that QE policies can alter long-term interest rates. For example, Gagnon, Raskin, Remache, and Sack (2010) present an event-study of QE1 that documents large reductions in interest rates on dates associated with positive QE announcements. Swanson (2011) presents confirming event-study evidence from the 1961 Operation Twist, where the Fed/Treasury purchased a substantial quantity of long-tem Treasuries. Apart from the event-study evidence, there are papers that look at lower frequency variation in the supply of long-term Treasuries and documents causal effects from supply to interest rates (see, for example, Krishnamurthy and Vissing-Jorgensen (2010)).[4]

While it is clear from this body of work that QE lowers medium and long-term interest rates, the channels through which this reduction occurs are less clear. The main objective of this paper is to evaluate these channels. We review the principal theoretical channels through which QE may operate and then examine the event-study evidence with an eye towards distinguishing among these channels. We furthermore supplement previous work by adding evidence from QE2 and evidence based on intra-day data. Studying intra-day data allows us to document price reactions and trading volume in the minutes after the main announcements, thus increasing confidence that any effects documented in daily data are causal.

It is necessary to understand the channels of operation in order to evaluate the success of policy. Here is an illustration of this point: Krishnamurthy and Vissing-Jorgensen (2010) (hereafter, KVJ) present evidence for a channel whereby changes in long-term Treasury supply work through altering the safety premia on near zero default risk long-term assets. That is, under their theory, QE works particularly to lower the yields of bonds which are extremely safe, such as Treasuries or Aaa bonds. But, even if a policy affects Treasury interest rates, such rates may not be the most policy relevant ones. A lot of economic activity is funded by debt that is not as free of credit risk as Treasuries or Aaas. For example, about 40 percent of corporate bonds are rated Baa or lower (for which we estimate that the demand for assets with near zero default risk

[3] http://www.newyorkfed.org/newsevents/speeches/2010/dud101001.html

[4] Other papers in the literature that have examined Treasury supply and bond yields include Bernanke, Reinhart and Sack (2004), Greenwood and Vayanos (2010), D'Amico and King (2010), and Hamilton and Wu (2010).

does not apply). Similarly, mortgage-backed securities issued to fund household mortgages are less safe than Treasuries due to the substantial pre-payment risk involved in such securities. If the objective of QE is to reduce interest rates paid by the majority of corporations and households which may then spur spending and economic growth, then examining supply effects on Treasury rates could be misleading.[5] One of the principal findings of this paper is that a Treasuries-only QE policy will have significant effects on long-term Treasury rates and rates on highly-rated corporate bonds, but smaller effects on mortgage rates. The large reductions in mortgage rates due to QE1 appear to be driven by the fact that QE1 involved large purchases of agency MBS. For QE2, which involved only Treasury purchases, we find a substantial impact on Treasury rates, but almost no impact on MBS rates. The main effect on Baa corporate bonds in QE2 appears to be through a signaling channel, which raises the question of whether or not it is necessary for the Fed to put their balance sheet at risk in order to signal lower future rates. Clouse, Henderson, Orphanides, Small, and Tinsley (2000) make similar arguments in their discussion of the theoretical channels for quantitative easing, but do not offer empirical evidence distinguishing among the channels. A principal contribution of the present paper is to use a variety of asset market data, including derivatives data, to distinguish among the channels of QE.

The next section of the paper lays out the channels through which QE may be expected to operate. We then present an event study of QE1 and evaluate the channels. Section 3 presents a similar event study and evaluation of channels for QE2. Section 4 presents regression analysis building on the work from KVJ to provide estimates of the expected effects of QE on interest rates. Section 5 concludes. All tables and graphs appear at the end of the paper.

2. Channels

a. Duration Risk Channel

Vayanos and Vila (2009) offer a theoretical model for the duration risk channel. Their one-factor model produces a risk premium on a bond of maturity t that is approximately the product of the duration of a maturity t bond and the price of duration risk, which in turn is a function of the amount of duration risk borne by the marginal bond market investor and this investor's risk

[5] A good example to illustrate this point is to consider the behavior of Treasury Bill rates in the fall 2008 period. Such rates were close to zero and substantially below most of other corporate borrowing rates. It would have been incorrect to look at the low Treasury Bill rate and conclude that credit was easy – the low rates reflect a high investor preference for extremely safe and liquid assets.

aversion. By purchasing long-term Treasuries, Agency debt, or Agency MBS, policy can reduce the duration risk in the hands of investors and thereby alter the yield curve, particularly reducing long-maturity bond yields relative to short-maturity yields. To deliver these results the model departs from a frictionless asset pricing model. The principal departure that generates the duration risk premium result is the assumption that the bond market is segmented and that there is a subset of risk-averse investors who bear (all or a lot of) the interest rate risk in owning bonds.

An important but subtle issue in using the model to think about QE is to ask whether the model applies narrowly to a particular asset class (e.g., only the Treasury market) or whether it applies broadly to all fixed income instruments. For example, if the segmentation is of the form that some investors had a special demand for 10 year Treasuries, but not 10 year corporate bonds (or mortgages or bank loans), then the Fed's purchase of 10 year Treasuries can be expected to affect Treasury yields, but not corporate bond yields. More broadly, if segmentation assumptions describe activity in only the Treasury market, then the model has implications for Treasury market yield curves, but not other fixed income yield curves. Vayanos and Vila (2009) do not take a stand on the issue. Greenwood and Vayanos (2010) offer evidence for how a change in the relative supply of long-term versus short-term Treasuries affects the spread between long-term and short-term Treasury bonds. This evidence also does not settle the issue, because it only focuses on Treasury data.

Recent studies on QE have interpreted the model as being about the broad fixed income market (see Gagnon, Raskin, Remache, and Sack, 2010), and that is how we proceed.[6] Under this interpretation, the duration risk channel has two principal predictions:

i. QE decreases the yield on all long-term nominal assets, including Treasuries, corporate bonds, and mortgages.
ii. The effects are proportional to the duration of a bond, with larger effects for longer duration assets.

[6] Note however that the broad fixed income market is much larger than the Treasury market, so that, under the Vayanos and Vila (2009) model, the Fed's purchase of duration risk should be expected to have a smaller effect on interest rates via this broad market channel.

b. Liquidity Channel

The QE strategy involves purchasing long-term securities and paying by increasing reserve balances. Reserve balances are a more liquid asset than long-term securities. Thus, QE increases the liquidity in the hands of investors and thereby decreases the liquidity premium on the most liquid bonds. There are many theoretical references for the liquidity channel. Almost all of the work on the effects of open market operations describes a liquidity channel.

It is important to emphasize that this channel implies an *increase* in Treasury yields. That is, it is commonly thought that Treasury bonds carry a liquidity price premium, and that this premium has been high during particularly severe periods of the crisis. An expansion in liquidity can be expected to reduce such a liquidity premium and increase yields. This channel thus predicts that:

i. QE raises Treasury yields, rather than lowers them.

ii. QE produces large effects for liquid assets, and no effects for illiquid assets.

c. Safety Premium Channel

Krishnamurthy and Vissing-Jorgensen (2010) offer evidence that there are significant clienteles for long-term safe (i.e., near zero-default-risk) assets that lower the yields on such assets.[7] The evidence comes from relating the spread between Baa bonds and Aaa bonds (or Agency bonds) to variation in the supply of long-term Treasuries, over a period from 1925 to 2008. They report that when there are less long-term Treasuries, so that there are less long-term safe assets to meet clientele demands, the spread between Baa and Aaa bonds rises.

The safety channel of KVJ is not the same as the risk premium of a standard asset pricing model; it reflects a deviation due to clientele demand. A simply way to think about investor willingness to pay extra for assets with very low default risk is to plot an asset's price against its expected default rate. KVJ argue that this curve is very steep for low default rates, with a slope that flattens as the supply of Treasuries increases. Figure 1 illustrates the distinction. The bottom line is the C-CAPM value of a risky bond. As default risk rises, the price of the bond falls. The distance from this line up to the middle (solid) line illustrates the safety premium of KVJ; for

[7] Many discussions of the effects of QE refer to a "portfolio balance channel," without being precise on the nature of investor portfolio demand underlying this channel. The safety channel of KVJ makes precise a portfolio balance channel: investors have a clientele demand for near-zero default risk assets. We return to a discussion of the portfolio balance channel in the conclusion.

bonds that have very low default, the bond price rises as a function of the safety of the bond. The figure also illustrates the dependence of the safety premium on the supply of long-term Treasuries. The distance from the bottom line to the top line is the safety premium for a smaller supply of safe assets. The clientele demand shifts the premium up. This dependence on the premium on the supply of long-term Treasuries is how KVJ distinguish a standard risk premium explanation of defaultable bond pricing with the clientele-driven safety demand.

This same effect may be expected to play out in QE. However, there is a subtle issue in thinking about different asset classes in QE: Treasury and Agency bonds are clearly safe in the sense of offering an almost sure nominal payment; however Agency MBS has significant prepayment risk which means that it may not meet clientele safety demands. The safety channel thus predicts that:

i. QE involving Treasuries and Agencies lowers the yields on safe assets.
ii. The largest effects should occur for the safest assets, with no effects on low-grade debt such as Baa bonds or bonds with prepayment risk such as MBS.

We expect Baa bonds to be the relevant cutoff for these safety effects. First, such bonds are the boundary between investment grade and non-investment grade securities, so that if driven by safety clientele demands, the Baa bond forms a natural threshold. More rigorously, Longstaff, Mithal and Neis (2006) use credit default swap data from December 2000 to October 2001 to show that the component of yields that is hard to explain by purely default risk information is about 50 bps for Aaa and Aa rated bonds, and about 70 bps for lower-rated bonds, suggesting that the cutoff for bonds whose yields are not affected by safety premia is somewhere around the A/Baa rating.

d. Signaling Channel

Eggertson and Woodford (2003) argue that non-traditional monetary policy can have a beneficial effect in lowering long-term bond yields only if such policy serves as a credible commitment by the central bank to keep interest rates low even after the economy recovers (i.e., lower than what a Taylor rule may call for). Clouse, et. al. (2000) argue that such a commitment can be achieved when the central bank purchases a large quantity of long duration assets in QE. If the central bank raises rates, it takes a loss on these assets. To the extent that the central bank weighs such losses in its objective function, purchasing long-term assets in QE serves as a credible commitment to keep interest rates low. Furthermore, some of the Federal Reserve announcements regarding QE explicitly contained discussion of the Federal Reserve's policy on future Federal Funds rates. Markets may also infer that the Fed's willingness to undertake an unconventional policy like QE indicates that it will be willing to hold its policy rate low for an extended period.

The signaling channel affects all bond market interest rates, since lower future Federal Funds rates, via the expectations hypothesis, can be expected to affect all interest rates. We examine this channel by measuring changes in the prices of the Federal Funds futures contract, as a guide to market expectations of future Federal Funds rates.[8] The signaling channel should have the largest impact in lowering short/intermediate maturity rates rather than long maturity rates, since the commitment to keep rates low only lasts until the economy recovers and the Fed can sell the accumulated assets. Given forecasts of the duration of the current low-growth period, such maturities will be in the 1 to 3 year range. Federal Funds futures contracts only extend out only to 2 years. Thus, we also examine the yields on bonds of different maturities to discern this effect.

e. Prepayment Risk Premium Channel

QE1 involved the purchase of $1.25tn of Agency MBS. Gabaix, Krishnamurthy, and Vigneron (2007) present theory and evidence that mortgage prepayment risk carries a positive risk premium, and that this premium depends on the quantity of prepayment risk borne by mortgage investors. The theory requires that the MBS market is segmented and that a class of arbitrageurs who operate predominantly in the MBS market are the relevant investors in determining the pricing of prepayment risk. This theory is similar to the Vayanos and Vila (2009) explanation of the duration risk premium, and more broadly fits into theories of intermediary asset pricing (see He and Krishnamurthy, 2010).

This channel is particularly about QE1 and its effects on MBS yields, which reflect a prepayment risk premium:

i. QE1 lowers MBS yields relative to other bond market yields.

ii. QE2, which does not involve MBS purchases, does not affect MBS yields.

[8] Piazzesi and Swanson (2008) show that these futures prices reflect a risk premium, in addition to such expectations. As we explain, we adjust the futures prices to remove risk premium effects.

f. Default Risk Channel

Lower grade bonds such as Baa bonds carry higher default risk than Treasury bonds. QE may affect the quantity of such default risk as well as the price (i.e. risk premium) of the default risk. If QE succeeds in stimulating the economy, we can expect that the default risk of corporations will fall, and hence Baa rates will fall. Moreover, standard asset pricing models predict that investor risk aversion will fall as the economy recovers, implying a lower default risk premium. Finally, extensions of the intermediary pricing arguments we have offered above for pricing prepayment risk can imply that increasing health/capital in the intermediary sector can further lower the risk premium on default risk.

We use credit-default swap (CDS) rates to evaluate the importance of a default risk channel. A credit default swap is a financial derivative used to hedge against default by a firm. The "credit default swap rate" measures the percentage of face-value that must be paid as an annual insurance premium to insure against default on the bonds of a given firm. The 5-year CDS refers to an insurance contract that expires in 5 years, while the 10-year CDS refers to the same expiring in 10 years. We use these CDS to infer default risk at different maturities.

g. Inflation Channel

To the extent that QE is expansionary, it increases inflation expectations, and this can be expected to have an effect on interest rates. In addition, some commentators have argued that QE may increase tail risks surrounding inflation.[9] That is, in an environment where investors are unsure about the effects of policy on inflation, policy actions may lead to greater uncertainty over inflation outcomes. Others have argued that aggressive policy decreases uncertainty in the sense that it effectively combats the possibility of a deflationary spiral. Ultimately, this is an issue that can only be sorted out by data. We propose looking at the implied volatility on interest rate options, since a rise in inflation uncertainty will plausibly also lead to a rise in interest rate uncertainty and implied volatility. The inflation channel thus predicts:

i. QE increases the rate on inflation swaps as well inflation expectations as measured by the difference between nominal bond yields and TIPS.

ii. QE may increase or decrease interest rate uncertainty as measured by the implied volatility on swaptions.

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[9] See Calomiris and Tallman, 2010, op-ed, "In Monetary Targeting, Two Tails are Better than One."

Two explanations are in order on the measurements in (i) and (ii): First, a (zero-coupon) inflation swap is a financial instrument to hedge against a rise in inflation. The swap is a contract between a “fixed rate payor” and a “floating rate payor” that specifies a one-time exchange of cash at the maturity of the contract. The floating rate payor pays the realized cumulative inflation over the life of the swap as measured using the CPI index. The fixed rate payor makes a fixed payment, contracted at the initation of the swap agreement. In an efficient market, the fixed rate payment thus measures the expected inflation rate over the life of the swap.

Second, a swaption is a financial derivative on interest rates. The buyer of a call swaption earns a profit when the interest rate rises relative to the strike on the swaption. As with any option, following on the Black-Scholes model, the expected volatility of interest rates enters as an important input for pricing the swaption. The implied volatility is the expected volatility of interest rates as implied from current market prices of swaptions.

h. Summary

The channels we have discussed and our empirical approach can be summarized with a few equations. Suppose that we are interested in the real yield on a T-year long-term, risky, and illiquid asset such as a corporate or a mortgage loan. Denote this yield by $r_{risky, illiq, longterm}$. Also, denote the expected average interest rate over the next T years on a short-term safe and liquid nominal bond as $E[i_{safe, liq, short-term}]$, and the expected inflation rate over the same period as π^e. Then we can decompose the long-term rate as:

(Eq. 1)
$$\begin{aligned} r_{risky, illiq, long-term} = {} & E[i_{safe, liq, short-term}] - \pi^e \\ & + Duration \times P_{DurationRisk} \\ & + Illiquidity \times P_{Liquidity} \\ & + LackofSafety \times P_{Safety} \\ & + DefaultRisk \times P_{DefaultRisk} \\ & + PrepaymentRisk \times P_{PrepaymentRisk}. \end{aligned}$$

Each line in this equation reflects a channel we have discussed. The first line is the expectations hypothesis terms. The long-term rate reflects the expected average future real interest rate. The signaling channel for QE may affect $r_{risky, illiq, long-term}$ through the first line. Expected inflation can also be expected to affect long-term real rates. The second term reflects a duration risk premium that is a function of duration and the price of duration risk, as explained above. This decomposition is analogous to the textbook treatment of the CAPM, where the return on a given asset is decomposed as the asset's β multiplied by the market risk premium. The third term is the illiquidity premium we have discussed, which is likewise related to an asset's liquidity multiplied by the market price of liquidity. The next terms reflect the safety premium (the extra yield on the non-safe bond because it doesn't have the extreme safety of a Treasury bond), a premium on default risk, and for the case of MBS, a premium on prepayment risk.

The equation makes clear that a given interest rate can be affected by QE through a variety of channels. It is not possible to examine the change in say the Treasury rate to conclude how QE may work because different interest rates are affected by QE in different ways.

Our main empirical methodology to examining the various channels can be thought of as difference-in-difference approach. For example, in asking whether there is a liquidity channel that may affect interest rates, we consider the yield spread between a long-term Agency bond and a long-term Treasury bond and measure how this yield spread changes over the relevant QE event. The yield decomposition from Eq. 1 for each of these bonds is identical, except for the term involving liquidity. That is, these bonds have the same duration, safety, default risk, etc., but the Treasury bond is more liquid than the Agency bond. Thus the difference in yields between these bonds drills in on a liquidity channel. We examine how this yield spread changes over the QE event dates. We take this difference-in-difference approach in evaluating the liquidity, safety, duration, and prepayment risk channels.

In addition to the difference-in-difference approach, in some cases we use derivatives prices, which are affected by only a single channel, to separate out the effect of a particular channel. This is how we use the Federal Funds futures contracts, the CDS swap rates, the inflation swap rates, and the implied volatility on interest rate options.

3. Evidence from QE1

a. Event Study

Gagnon, et. al., (2010) provide an event study of QE1 based on the announcements of long-term asset purchases by the Federal Reserve in the late-2008 to 2009 period ("QE1"). These policies included purchase of mortgage-backed securities, Treasury securities and Agency securities. Gagnon, et. al., (2010) identify eight event dates beginning with the 11/25/08 announcement of the Fed's intent to purchase $500 bn of Agency MBS and $100bn of Agency debt, and running into the summer of 2009. We focus on the first five of these event dates (11/25/2008, 12/1/2008, 12/16/2008, 1/28/2009, and 3/18/2009), leaving out three later event dates on which only small yield changes occurred.

There was considerable turmoil in financial markets in the period from the fall of 2008 to the spring of 2009, which makes inference from an event-study somewhat tricky. Some of the assets we consider, such as corporate bonds and CDS, are less liquid. During a period of low liquidity, the prices of such assets may react slowly in response to an announcement. We deal with this issue by presenting two-day changes for all assets (from the day prior to the day after the announcement). In the data, for high liquidity assets like Treasuries, two-day changes are almost the same as one-day changes. For low liquidity assets, the two-day changes are almost always higher than one-day changes; there appears to be a continuation pattern in the yield changes.

The second issue that arises is that we cannot be sure that the identified events are in fact important events, or the dominant events for the identified event day. That is, other significant economic news arrives through this period and potentially creates measurement error problems for the event-study. To increase our confidence that QE1 announcements were the dominant news on the five event dates we study, Figure 2 presents graphs of intraday movements in Treasury yields and trading volume for each of the event dates. The figure is based on data from BG Cantor and the data graphed is for the on-the-run 10 year Treasury bond at each date. Yields graphed are averages by the minute and trading volume graphed is total volume by minute. The vertical lines indicate the minute of the announcement, defined as the minute of the first article covering the announcement in Factiva. These graphs show that the events identify significant movements in Treasury yields and Treasury trading volume and that the announcements do appear to be the main piece of news coming out on the event days, especially on 12/1/2008, 12/16/2008 and 3/18/2009. For 11/25/2008 and 1/28/2009, the trading volume graphs also suggests that the announcements are the main events, with more mixed evidence from the yield graphs for those days.

While it is likely that these five dates are most relevant event dates, it is possible that there are other “true” event dates that we have omitted. How does focusing on too limited a set of event dates affect inference? For the objective of analyzing through which channels QE operates, omitting true event dates reduces the power of our tests by increasing the noise in the sample, but does not lead to any biases.[10] For estimating the overall effect of QE, omitting potentially relevant dates could lead to an upward or downward bias depending on how QE affected the market’s perception of the probability or magnitude of QE.

Table 1 presents data on two-day changes in Treasury, Agency, and Agency MBS yields around the main event-study dates, spanning a period from 11/25/08 to 3/18/09. Over this period it became evident from Fed announcements that the government intended to purchase a large quantity of long-term securities. Across the five event dates, interest rates fell across the board on long-term bonds, consistent with a contraction of supply effect. Now consider the channels through which the supply effect may have worked.

In all tables we provide tests of the statistical significance of the rate changes documented, focusing on the total change shown in the last row of each table (for QE1 and QE2 separately). Statistical significance is assessed by regressing the daily changes for the variable in focus on 4 dummies: A dummy for whether there was a QE1 announcement on this day, a dummy for whether there was a QE1 announcement on the previous day, a dummy for whether there was a QE2 announcement on this day, and a dummy for whether there was a QE2 announcement on the previous day. This regression is estimated on daily data from 2008 to November 4, 2011, using OLS but with robust standard errors to account for heteroscedasticity. F-tests for the QE dummy coefficients being zero are then used to assess statistical significance. When testing for statistical significance of 2-day changes, the F-test is a test of whether the sum of the coefficient on the QE dummy (QE1 or QE2) and the coefficient on the dummy for a QE announcement (QE1 or QE2) on the previous day, is equal to zero. We are unable to present statistical tests for results involving CDS rates because we only have CDS data for the main event days.

[10] We thank Gabriel Chodorow-Reich for clarifying this point.

b. Duration Risk Channel

Consistent with the duration risk hypothesis, the yields of many longer term bonds in Table 1 fall more than the yields of shorter maturity bonds. The exception here is the 30 year Treasury bond, where the yield falls less than the 10 year bond.

However, there is other evidence that the duration risk channel cannot explain. There are dramatic differences in the yield changes across the different asset classes. Agency bonds, for example, experience the largest fall in yields. The duration risk channel cannot speak to these effects as it only prescribes effects that depend on bond maturity. The corporate bond data also cannot be explained by the duration risk channel. Table 2 presents data on corporate bond yields of intermediate duration (around 4 year duration) or long duration (around 10 year duration), as well as these same yields with the impact of changes in CDS rates taken out. We adjust the yield changes using CDS changes to remove any effects due to a changing default risk premium and thereby isolate duration risk premium effects. We construct CDS rate changes by rating category as follows. We obtain company-level CDS rates for from CMA via Datastream. We classify companies into ratings categories based on the value-weighted average rating of the company's senior debt with remaining maturity above 1 year, using bond information from FISD and TRACE. For each QE date we then calculate the company level CDS rate change and the value-weighted average of these changes by ratings category, with weights based the company's senior debt with remaining maturity above 1 year (and with weights calculated based on market values on the day prior to the event day).

The CDS adjustment makes a substantial difference in interpreting the evidence. In particular, there is a large fall in CDS rates for lower grade bonds on the event dates, suggesting that default risk/risk premia fell substantially with QE, consistent with the default risk channel (we discuss this further below). Given the CDS adjustment, there is only a small change in the yields of Baa and lower bonds. Moreover, there is no apparent pattern across long and intermediate maturities in the changes in CDS-adjusted corporate bond yields.[11] These observations suggest that we need to look to other channels to understand the effects of QE.

[11] We show below that there is no maturity effect in CDS rates so using CDS rates of different maturity for long and intermediate corporate bonds is unlikely to change our conclusion about the absence of a duration risk channel.

c. Liquidity Channel

The most liquid assets in Table 1 are the Treasury bonds. The liquidity channel predicts that these yields should *increase* with QE. They do not increase; however, note that they fall much less than the yields on Agency bonds which are less liquid. That is the Agency-Treasury spread falls with QE. For example, the 10 year spread falls by 199-107=92 basis points. This is a relevant comparison because 10 year Agencies and Treasuries have the same default risk (especially since the government placed FNMA and FHLMC into conservatorship in September 2008), and are duration matched. Thus this spread isolates a liquidity premium. Consistent with the liquidity channel, we see that the equilibrium price premium (yield discount) for liquidity falls substantially.

d. Safety Channel

The Agency bonds will be particularly sensitive to the safety effect. These bonds are not as liquid as the Treasury bonds, but do have almost the same safety as Treasuries. The fall in 10 year Agency yields is 199 bps, which is the largest effect in the table. This suggests that the safety channel is one of the dominant channels for QE1. As we have just noted, Treasuries fall less than the Agencies because the liquidity effect runs against the safety effect.

The corporate bond evidence is also consistent with a safety effect. The CDS-adjusted yields on Aaa bonds, which are close to default free, fall substantially, while there is close to no effect on the non-investment grade bonds. Finally, since Agencies are safer than Aaa corporate bonds, the safety channel prediction that the former bond yields fall more than the latter is also confirmed in the data.

e. Signaling Channel

Figure 3 graphs the yields on the monthly Federal Funds futures contract, for contract maturities from March 2009 to October 2010. The pre-announcement average yield curves are computed on the day before each event and then averaged across event dates. The post-announcement average yield curve is computed likewise for the day after the event dates. Dividing the downward shift from the initial to the post-announcement average yield curve by the slope of the initial average yield curve tells us how much the policy shifted the rate cycle forward in time. The graph shows that, on average, each QE announcement “shifts” an anticipated rate hike cycle by the Fed later by a little over one month. Evaluating the forward shift at the yield of the March 2010 contract, the total effect of the five QE announcements is to shift anticipated rate increases later by 6.3 months. This effect is consistent with the signaling channel whereby the Fed's portfolio purchases signals a commitment to keep the Federal Funds rate low.

Table 4 reports the one and two-day change in the yields of the 3rd month, 6th month, 12th month, and 24th month futures contracts, across the five event dates. We aggregate by, for example, the 3rd month rather than a given contract-month (e.g., March), because it is more natural to think of the information in each QE announcement as concerning how long from today rates will be held low (on the other hand, for plotting a yield curve it is more natural to hold the contract-month fixed, as we did above in Figure 3). The two-day decrease in the 24th month contract is 40 basis points.[12]

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[12] Piazzesi and Swanson (2008) show that Federal Funds futures contracts include a risk premium so that there is considerable error in simply inferring expected future Federal Funds rates from these contracts. Moreover, they show that this risk premium varies positively with the level of short-term rates (so that when rates are lower, the risk premium is lower), and that it varies negatively with employment growth or other measures of the business cycle. To deal with this issue, we proceed as follows. Using monthly data from December 1988 to November 2011, we replicate the Piazzesi-Swanson result on the forecasting power of the futures contract. In particular, we estimate the relation between the realized Federal Funds rate n-months from today and the yield on the today's futures contract of maturity n. We also include data on the annual growth rate of non-farm payrolls (this month relative to same month the prior year), following Piazzesi and Swanson. For n=3, the coefficient on the futures contract is 0.92 (significant at 1% level), while for n=6, the coefficient is 0.82 (significant at 1% level). These numbers are very close to the Piazzesi-Swanson results. The 0.82 number for n=6 indicates that a decrease in today's yield on the futures contract of 10 basis points leads to subsequent decrease of the Federal Funds rate, 6 months from today, of 8.2 basis points. The difference of 10 - 8.2 =1.8 basis points is a risk premium that an investor can earn by purchasing the futures contract today. The 0.82 coefficient thus is an adjustment factor that we multiply the 6th month number in Table 2 by in order to infer the change in the market expectations of the Federal Funds rate 6-months from today. Because of data limitations (short time series of data for Fed funds futures beyond 6 month maturity), we only run the regression using n=3 and n=6. However, we are most interested in inferring changes in expectations in the 12th month. Based on the pattern that the n=3 coefficient is less than the n=6 coefficient, it is likely that the true coefficients for the 12th month is less than or equal to 0.82. If we use 0.82 as an adjustment factor, we find that two-day change in the expected Federal Funds rates 12 months out is 27 basis points. This is an upper bound on the signaling effect on the short rate 1 year out both because of the use of the 0.82 coefficient, and because QE likely improved the employment outlook which will tend to reduce

How much effect can the signaling channel have on longer term rates? The difficulty in assessing the effects on longer rates is that we cannot precisely measure changes in the expected future Federal Funds rates for horizons over 2 years due to the lack of Federal Funds futures contracts. An *upper* bound on the signaling effect can be found by extrapolating the 40 bps fall in the 24th month contract to all horizons. This is an upper bound because it is clear that at longer horizons, market expectations should reflect a normalization of the accommodative current Fed policy so that signaling should not have any effect on rates at that horizon. Nevertheless, with the 40bp number, equation 1 predicts that rates at all horizons fall by 40bps.

A second approach to estimating the signaling effect is to build on the observation that QE shifted the path of anticipated rate hikes by about 6 months. Signaling affects long term rates by changing the expectations term in equation 1, $E\left[i_{safe, liq, short-term}\right]$. Consider the expectations term for a T-year bond:

$$E\left[i_{safe, liq, short-term}\right] = \frac{1}{T}\int_{t=0}^{T} i_t^{ff} dt,$$

where, i_t^{ff} is the expected federal funds rate t years from today. Let us use $i_{t,prior}^{ff}$ to denote the path described by the federal funds rate as expected by the market *prior* to QE announcements. Suppose that QE policy signals that the rate is going to be held at $i_{0,prior}^{ff}$ for the next 6 months, and thereafter follow the path indicated by $i_{t,prior}^{ff}$ (such that the rate at t=0.5 years with the policy in place is what the rate would have been in at t=0 absent the policy). That is, QE simply shifts an anticipated rate hike cycle later by 6 months. Then, the decrease in the expectations term for a T-year bond is,

$$\Delta E\left[i_{safe, liq, short-term}\right] = \frac{1}{T}\int_{t=T-0.5}^{T} (i_{0,prior}^{ff} - i_{t,prior}^{ff})\, dt.$$

The first point to note from this equation is that it indicates that the signaling effect is decreasing in maturity (i.e. T). Here is a rough check on how large the signaling effect can be. Suppose that $i_{0,prior}^{ff}$ is 0%, which is as low as the federal funds rate traded over this period.

the risk premium in the Fed funds futures, implying that some additional component of futures rate decline is due to a reduction in the risk premium rather than expected future short rates. For the 24th month contract, this computation gives an upper bound of 33 bps.

Consider the $i_{t,prior}^{ff}$ term next. The 2-year Federal Funds futures contract, which is the longest contract traded, indicated a yield as high as 1.5% over this period. But expected Federal Funds rates out to say 10 years are likely to be much higher than that. Over the QE1 period the yield curve between 10 and 30 years was relatively flat, with levels of Treasury rates at 10 and 30 years as high as almost 4%. Thus, consider a value of $i_{t,prior}^{ff}$ of 4% to get an upper bound on this signaling effect. For a 10 year bond, the change is 20bps, while for a 30 year bond, the change is about 7bps. At the 5-year horizon, given the slope of the yield curve, $i_{t,prior}^{ff}$ is lower than 4%. We use 3.5%, which is based on considering the 5 and 7 year Treasury yields, implying a signaling effect of 35bps for the 5-year horizon.

Our two ways of computing the signaling effect indicates moves in the range of 20 to 40 bps out to 10 years. This effect potentially explains the moves in the CDS-adjusted Baa rates of 33bps (long) and 19bps (intermediate). It also can help explain the fall in the 1-year Treasury yield of 25 bps.

On the other hand, longer term rates move much more substantially than shorter term rates. Longer term Treasuries and Agencies fall 100 to 200 bps, and much more than the 3 year (and shorter) bond yields. In the corporate bonds of Table 2, there is no apparent maturity effect. Thus, to understand the more substantial movements of long-term rates we need to look to other channels and, in particular, the safety and prepayment risk channels.

f. Prepayment Risk Channel

Agency MBS yields fall by 128 bps for 30-year bonds and 98 bps for 15-year bonds. There are two ways to interpret this evidence. It is possible that this is due to a safety effect – the government guarantee behind these MBS may be worth a lot to investors so that these securities carry a safety premium. The safety premium then rises, as with the Agency bonds, decreasing Agency MBS yields. On the other hand, the Agency MBS carry significant prepayment risk and are unlikely to be viewed as safe in the same way as Agency bonds or Treasuries (where safety connotes the almost certainty of nominal repayment). In empirically analyzing Agency MBS rates as well as the rate on 30-year conventional household mortgages (using historical data going back to the 1960s, but not reported here for brevity) we have found no effects of Treasury supply on the spreads between Baa rates and Agency MBS, which leads us to conclude that Agency MBS rates, like Baa rates, do not carry safety or liquidity premia.

Yet, Agency MBS fall more than Agency bonds. We think that a more likely explanation is market segmentation effects as in Gabaix, Krishnamurthy and Vigneron (2007). The government purchase of MBS reduces the prepayment risk in the hands of investors, and thereby reduces MBS yields. The effect is higher for the 30 year than the 15 year because the longer bonds carry more prepayment risk.

Additionally, Fuster and Willen (2010) show that the large reductions on agency MBS rates around 11/25/2008 were quickly followed by reductions in mortgage rates offered by mortgage lenders to households.

g. Default Risk Channel

We have noted earlier from Table 2 that QE appears to reduce default risk or default risk premia, which particularly affects the interest rates on lower grade corporate bonds. The table shows that CDS rates of the Aaa firms do not change appreciably with QE. There is a clear pattern across the ratings, going from Aaa to B, whereby higher credit risk firms experience the largest fall in CDS rates. This evidence suggests that QE had a significant effect through default risk and default risk premia.

h. Inflation Channel

The above analysis focuses on nominal rates. To assess effects on real rates, one further needs information about the impact of QE1 on inflation expectations. Table 3 presents the relevant data.

The first columns in the table are for inflation swaps. The 10-year inflation swap is the fixed rate in the 10-year zero coupon inflation swap, and thus a market-based measure of expected inflation over the next 10 years (see Fleckenstein, Longstaff and Lustig (2010) for information on the inflation swap market). This data suggests that inflation expectations increased by between 36 and 95 basis points, depending on maturity.

The second set of columns present data on TIPS yields. We compare these yield changes to those from nominal bonds to evaluate the change in inflation expectations. Based on the evidence of the existence of significant liquidity premia on Treasuries, it is inappropriate to compare TIPS to nominal Treasuries. If investors' safety demand did not apply to real safe bonds such as TIPS, then the appropriate nominal benchmark is the CDS-adjusted Baa bond. On the other hand, if long-term safety demand also encompassed TIPS, then it is more appropriate to use the CDS-adjusted Aaa bond as benchmark. We are unaware of definitive evidence that settles the issue. From Table 1, the CDS-adjusted long maturity Aaa (Baa) bond falls in yield by 63 (33) bps, while the intermediate maturity bond falls in yield by 75 (19) bps. Matching the 63 (33) bps change to the 187 bps change in the 10 year TIPS, we find that inflation expectations increased by 120 (154) bps at the 10 year horizon. At the 5 year horizon, based on the 75 (19) bps change in CDS-adjusted intermediate maturity Aaa (Baa) bond and 144 bps change in TIPS, we find that inflation expectations increased by 69 (125) bps. Benchmarking to the Aaa bond produces results similar to those from the inflation swaps.

Together these two sets of data suggest that the impact of Fed purchases of long-term assets on expected inflation was large and positive.

We also evaluate the inflation uncertainty channel. The last column in Table 3 reports data on implied volatilities from interest rate swaptions (i.e., the option to enter into an interest rate swap). The data is the Barclays implied volatility index. The underlying maturity for the swap ranges from 1 year to 30 year, involving options that expire from 3 months to 20 years. The index is based on the weighted average of implied volatilities across the different swaptions.

The average volatility measure over the QE time period is 103 bps, so that the fall of 37 bps is substantial. Thus, it appears that QE reduced rather than increased inflation uncertainty.

The other explanation for this fall in volatility is segmented markets effects. MBS have an embedded interest rate option that is often hedged by investors in the swaption market. Since QE involved the purchase of MBS, investors have a smaller demand for swaptions and hence implied volatility on swaptions fall. This latter explanation is often the one given by practitioners for changes in swaption implied volatilities. Notice, however, that volatility is essentially unchanged on the first QE1 event date, which is the event that drives the largest changes in MBS yields. This could indicate that the segmented markets effects are not important, with volatility instead driven by the inflation uncertainty channel.

i. Summary

QE1 significantly reduced yields on safe assets, including Treasuries, Agencies and highly-rated corporate bonds, with liquidity effects working in the opposite direction. For the rates such as the Baa corporate bond or MBS yields, QE has effects through a reduction in default risk/default risk premia and a reduced prepayment risk premium. There is also evidence that QE decreased the yields on bonds, particularly shorter maturity bonds, via the signaling channel. But the signaling channel effects are small compared to the safety channel effects. On the other hand, there is little evidence for the duration risk premium channel. There is evidence that QE increased inflation expectations, but reduced inflation uncertainty. This latter point implies that real rates fell for a wide variety of borrowers.

Finally, note that these effects are all sizable and probably much more than we should expect in general. This is because the November 2008 to March 2009 period is an unusual financial-crisis period in which the demand for safe assets was heightened, segmented market effects were apparent across many markets, and intermediaries suffered from serious financing problems. In such an environment, supply changes should be expected to have a large effect on interest rates.

3. Evidence from QE2

a. Event Study

We perform an event study of QE2 similar to that of QE1. There are two relevant sets of events in QE2. First, in the 8/10/2010 FOMC statement, the committee announces:

"the Committee will keep constant the Federal Reserve's holdings of securities at their current level by reinvesting principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities."

Prior to this announcement, market expectations were that the Fed would let its MBS portfolio runoff,[13] thereby reducing reserve balances in the system and allowing the Fed to exit from its non-traditional monetary policies. Thus, the announcement of the Fed's intent to continue QE revised market expectations. Moreover, the announcement indicated that the QE would shift towards longer-term Treasuries, and not Agencies or Agency MBS as in QE1. As a back-of-the-

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[13] See Fed Chairman Bernanke's Monetary Policy Report to Congress on July 21, 2010, discussing the "normalization" of monetary policy. The issue is also highlighted in Bernanke's testimony on March 25, 2010 on the Federal Reserve's exit strategy.

envelope computation, suppose that the prepayment rate for the next year on $1.1tn of MBS was 20%.[14] Then the announcement indicated that the Fed intended to purchase $220bn of Treasuries over the next one year, and $176bn over the subsequent year, etc. It is unclear from the announcement how long the Fed expected to keep the re-investment strategy in place.

The 9/21/10 FOMC announcement reiterates this message:

"The Committee also will maintain its existing policy of reinvesting principal payments from its securities holdings."

The second type of information for QE2 pertains to the Fed's intent to expand its purchases of long-term Treasury securities. In the 9/21/10 FOMC statement, the fourth paragraph states:

"The Committee will continue to monitor the economic outlook and financial developments and is prepared to provide <u>additional</u> accommodation if needed to support the economic recovery […]" (emphasis added)

This paragraph includes new language relative to the corresponding paragraph in the 8/10/2010 FOMC statement which read: "*The Committee will continue to monitor the economic outlook and financial developments and will employ its policy tools as necessary to promote economic recovery and price stability*." The new language in the 9/21/2010 statement follows the third paragraph of that statement in which the FOMC reiterates its intention to maintain its target for the federal funds rate and reiterates its policy of reinvesting principal payments from its securities holdings. The new language was read by many market participants as indicating new stimulus by the Fed, and particularly an expansion of its purchases of long-term Treasuries. For example, Goldman Sachs economists in their market commentary on 9/21/2010 refer to this language and conclude that the Fed intends to purchase up to $1 trillion of Treasuries (see "FOMC Rate Decision - Fed Signals Willingness to Ease Further if Growth or Inflation Continue to Disappoint," 9/21/2010, Hatzius, McKelvey, Tilton and Stehn).

The following announcement from the 11/3/2010 FOMC statement makes such an intention explicit:

[14] The Fed's holdings of MBS on August 4, 2010 was $1,118bn, while it was $914bn on June 22, 2011 (source: H4 report of the Federal Reserve). That is an annualized decline of 20.6%.

“The Committee will maintain its existing policy of reinvesting principal payments from its securities holdings. In addition, the Committee intends to purchase a further $600 billion of longer-term Treasury securities by the end of the second quarter of 2011.”

The 11/3 announcement was widely anticipated. According to the Wall Street Journal, a WSJ survey of private sector economists in early October of 2010 found that the Fed was expected to purchase about $750 billion in QE2.[15] We have noted above the expectation, as of 9/21/2010, by Goldman Sachs' economists of $1 trillion of purchases. Based on this, one would expect the 11/3/2010 announcement to have little effect (estimates in the press varied widely, but the actual number of $600 bn was in the range of numbers commonly mentioned).

Figure 4 presents intraday data on the 10-year Treasury bond yield around the announcements times of the FOMC statements. The 8/10 announcement appears to be significant news for the Treasury market, reducing the yield in a manner that suggest that market expectations over QE were revised up. The 9/21 announcement is qualitatively similar. At the 11/3 announcement**,** Treasury yields increased but then fell some. The reaction suggests that markets may have priced in more than a $600bn QE announcement.

In our event study, we aggregate across the 8/10 and 9/21 events, which seem clearly to be driven by upward revisions in QE expectations. We do not add in the change from the 11/3 announcement as it is unclear whether only the increase in yields after than announcement or also the subsequent decrease was due to QE2 (furthermore, the large two-day reaction to the 11/3 announcement may not be due to QE2 since a lot of it happened the morning of 11/4 around the time new numbers were released for jobless claims and productivity). As noted in Section 3a, given our objective of understanding the channels of QE, it is important to focus on events that we can be sure are QE relevant.

Additionally, we present information for both 1-day changes and 2-day changes, but focus on the 1-day change in our discussion. This is because market liquidity had normalized by the fall of 2010, and looking at the 2-day changes would therefore likely add noise to the data.

[15] WSJ, Oct 26, 2010, "Fed Gears Up for Stimulus".

b. Analysis

Table 5 provides data on the changes in Treasury, Agency and Agency MBS yields over the event dates. Table 6 provides data on changes in corporate bond yields, CDS, and CDS-adjusted corporate yields.

Effects of QE2 on yields are consistently much smaller than the effects found for QE1. This could be partially due to omissions of relevant additional event dates for QE2. We considered various additional events (e.g. speeches by Fed officials) but, using intra-day Treasury yield data, did not find any days with dramatic Treasury yield declines right around the events. This does not mean that considering only a few QE2 event dates captures all of the impact of QE2, only that the market may have updated its QE2 perceptions due to e.g. bad economic news. Decomposing the yield impact of, for example, a GDP announcement into its ``standard effects'' and its indirect effect due to its impact on the likelihood of QE is difficult.

The fact that the effects of QE2 are fairly small makes it more difficult to discern all of the various channels in QE2 than in QE1. That said, here are some conclusions regarding the channels:

- There is significant evidence of the signaling channel. The 12th month Federal Funds futures contract from Table 4 falls by 4 bps. The 24th month contract falls by 11 bps. Extrapolating out from this 24th month contract suggests that we can explain moves in longer term rates of up to 11 bps following our first approach outlined in our discussion of signaling for QE1. Turning to our second approach, Figure 5 plots the average pre- and post- QE2 yield curves from the Federal Funds futures contracts. The graph suggests a shift later of the anticipated rate hike cycle. We can again estimate how large this shift is. Because the slope of the futures curve from Figure 5 is not constant, the computation is sensitive to exactly which point you use to evaluate the time shift. Using the slope and vertical shift at July 2012, we estimate the time shift is 3.2 months, while using the slope and vertical shift at July 2011, we estimate the time shift at 2.1 months. The 2.1 month number implies a fall in 5 year rates of 12 bps, a fall in 10 year rates of 8 bps, and a fall in 30 year rates of 2 bps. The 3.2 month number implies a fall in 5 year rates of 18 bps, a fall in 10 year rates of 12 bps and a fall in 30 year rates of 4 bps. The fall of 18 bps in the

5 year rate from this computation is too large relative to the 11 bps upper bound from our first approach, suggesting that the 2.1 month computation is more plausible.

These numbers appear in line with the CDS adjusted corporate bond yield changes. Note also that the intermediate rates in Table 6 fall more than the long rates, consistent with the signaling channel. Thus, the signaling channel can plausibly explain all of the movements in the corporate bond rates, except for the Ba long and B long (see below).

The 10-year Treasuries and Agencies from Table 5 move more than the corporate bond rates or our signaling estimates, suggesting that there are other channels at work. The Agency MBS yields fall, but not as much as signaling would suggest. This is possibly because the fall in rates also increased the value of the prepayment option in the MBS, so that the MBS yields do not fall as much as signaling would imply.

- There is also evidence for a safety channel. 10-year Agency yields and Treasury yields, which are both near zero default-risk fall in yield more than the CDS-adjusted corporate bond yields. If we use 8 bps in the CDS-adjusted Baa long to benchmark the signaling effect, then the safety effect is about 10 bps.

  Contrary to the prediction of the safety channel, and unlike the QE1 experience, the CDS-adjusted Aaa bond does not move more than the CDS-adjusted Baa bonds. It is plausible that since the overall effects in QE2 are much smaller than that of QE1, noise in yields makes it harder to discern this effect. The Aaa bond yields come from a small sample since only a few companies remain Aaa currently.

- There does not appear to be a substantial duration risk premium channel. Given that the size of the signaling channel is roughly the same as the decline in the CDS-adjusted corporate rates, there is no additional yield decline to be explained by a duration risk premium reduction.

- There does not appear to be a liquidity channel. Treasury and Agency yields fall by nearly the same amounts, so that their spread, which can measure liquidity, appears unchanged. This result is plausible because liquidity premia in markets were quite low in late 2010, as market liquidity conditions had normalized. Consider the following data (on 10/22/2010):

	Treasury Bill	Tier 1 Non-Financial CP
1 week	10bps	19bps
1 month	12	21
3 month	12	23

  The premium on the more liquid 1 week bill relative to the 3 month bill is only 2 basis points. The premium on the more liquid 3 month bill relative to 3 month CP is only 11 basis points. The latter premium also reflects some credit risk and tax effects. Part of the reason why liquidity premia are so low is that government policy had already provided a large supply of liquid assets to the private sector. Consider that the Fed had already increased bank reserves substantially. In June 2007, reserve balances totaled $44bn. As of September 2010, reserve balances totaled close to $1,040bn. Furthermore, the government had increased the supply of Treasury bills from $865bn to $1783bn over this same period. These arguments suggest that the effects on liquidity premia should be negligible via the liquidity channel.

- There is no evidence for a credit risk channel as the CDS rates rise, especially for lower-grade bonds. This may indicate that QE2 (unlike QE1) did not have a substantial stimulating effect on the economy. It is also possible that the increase in CDS rates (as opposed to simply unchanged CDS rates) is due to the market inferring from the Fed's decisions to pursue QE2 that the economy was in worse shape than previously thought.

- Table 7 provides data on inflation swaps and TIPS yields for the event dates to analyze effects on inflation expectations. Inflation expectations rise with QE2. The 10 year inflation swap rises by 5 bps, while the 30 year swap rises by 11 bps. The 10 year TIPS falls by 25 bps. Comparing this number to the CDS-adjusted fall in the Baa long bond, we find that inflation expectations rise by 17 bps. The implied volatility on swaptions falls by 3 bps, indicating a slight decrease in inflation uncertainty.

c. Summary

The QE2 data strongly suggests three primary channels for this policy. The signaling channel lowered yields on intermediate and long-term bonds by in the range of 8 to 10 bps. The safety channel lowered yields on low-default risk long term bonds by an additional 8 to 10 bps. Furthermore, there is significant evidence for an increase in inflation expectations, suggesting that real rates fell for all borrowers.

The main effect on the nominal rates that are most relevant for household and many corporations -- mortgage rates and rated on lower-grade corporate bonds -- was thus through the signaling and inflation channels, as opposed to resulting directly for the QE2 Treasury purchases. The finding of a significant role for signaling is consistent with the market's reaction to the August 9, 2011 FOMC statement which stated that: "*The Committee currently anticipates that economic conditions--including low rates of resource utilization and a subdued outlook for inflation over the medium run--are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013."* From August 8 to 9, Treasury rates declined by 20, 20, 14, and 12 bps at the 5, 10, 20 and 30 year maturities, respectively. An interesting question is thus whether the Fed could have achieved the signaling and inflation impact on yields seen in QE2 from a commitment as in the August 9, 2011 statement, and thus without taking on additional balance sheet risk.

4. Regression Analysis of the Safety Channel

The event-study evidence is useful in identifying channels for QE. While it provides some guidance on the magnitudes of the effects through QE, it is hard to precisely interpret the numbers because event study measures are dependent on the dynamics of expectations through the event. That is, the asset market reaction depends on the change in the expectation of QE over the event. We have no direct way of precisely measuring such an expectations change, nor determine whether the event study is likely to over- or understate the effects of QE. In addition, the QE1 event occurs in highly unusual market conditions, so that it is hard to extrapolate numbers from that period to more normalized conditions. As such, it is valuable to find alternative approaches to estimating the impact of QE. In this section, we use regression analysis to provide such estimates.

a. KVJ regressions

We build on the regression analysis from KVJ to estimate the effect of a purchase of long-term securities via the safety channel. We focus on the safety channel because it appears to be a dominant effect from the event studies.

The KVJ regression approach can be explained through Figure 1. Consider the yield (or price) difference between a low default risk bond, such as a Treasury, and a Baa bond. This yield difference includes both a default risk premium due to standard risk considerations and a safety premium component due to clientele demands for particularly safe assets. We disentangle the default risk and safety premium by observing that the safety premium is decreasing in the supply of safe assets, including Treasuries, while the default risk component can be controlled for using empirical default measures. The empirical approach is to regress the Baa-Treasury spread on the supply of Treasuries as well as standard measures of default.

In KVJ, we mainly focus on the effect of changes in the total supply of Treasuries, irrespective of maturity, on bond yields. For evaluating QE, we are interested more in asking how a change in the supply of long-term Treasuries will affect yields. Accordingly, we construct a maturity-based measure of debt supply as follows. For each Treasury issue, we compute the market value of that issue multiplied by the duration of the issue divided by 10.[16] We normalize by 10 to express the supply variable in "ten-year equivalents." We then sum these values across Treasury issues with remaining maturity of 2 years or more. Denote the sum as LONG-SUPPLY. We also construct the (unweighted) market value across all Treasury issues (TOTAL-SUPPLY), including those with a remaining maturity of less than 2 years.

We then regress the spread between the Moody's Baa corporate bond index and the long-term Treasury yield (Baa-Treasury) on the ln(LONG-SUPPLY/GDP) instrumented by TOTAL-SUPPLY/GDP, and squares and cubes of TOTAL-SUPPLY/GDP. The regression includes default controls of stock market volatility (i.e., standard deviation of weekly stock returns over the preceding year) and the slope of the yield curve (10 year Treasury yield minus 3-month

[16] We use monthly data on prices and bond yields from the CRSP Monthly US Treasury Database base to empirically construct the derivative of price with respect to yield. The derivative is used to compute the duration.

yield). The regressions are estimated via OLS, with standard errors adjusted for an AR(1) correlation structure. It is important to instrument for LONG-SUPPLY because the maturity structure of government debt is chosen by the government in a way that could be correlated with spreads. TOTAL-SUPPLY is a good instrument for LONG-SUPPLY and plausibly exogenous to the safety premium. See KVJ for further details of the estimation method. The regressions are estimated using annual data from 1949 to 2008. The regression is:

$$Spread_t = Default\ Controls_t + \beta \ln(LONG - SUPPLY_t/GDP_t) + \epsilon_t$$

instrumented by TOTAL-SUPPLY/GDP, and squares and cubes of TOTAL-SUPPLY/GDP.
The term $\beta \ln(LONG - SUPPLY/GDP)$ is the premium of interest in this regression. We evaluate the effect of a QE by evaluating this premium term at the pre-QE and post-QE values of LONG-SUPPLY.

The β coefficient is -0.83 (*t*-statistic = -5.83). If we construct the spread as Aaa-Treasury, the result is -0.51 (*t*-statistic = -4.64). For the Baa-Aaa spread, the result is -0.31 (*t*-statistic = -4.64).

As we explain in KVJ, the Baa-Treasury spread reflects both a liquidity premium and a safety premium. The coefficient from the Baa-Aaa regression is a pure read on the safety premium, because Baa bonds and Aaa bonds are equally illiquid. However, it is an underestimate of the safety effect as may be reflected in Treasuries or Agencies because while Aaa are safe, they still contain more default than Treasuries or Agencies. For example, Moody's reports that over 10 years, the historical average default probability of a bond that is rate Aaa today is 1% (while it is likely close to 0% for Treasuries and is close to 10% for Baa bonds).

The Baa-Treasury spread is likely an overestimate of the safety premium. That is, it has the advantage that the Treasury yield is close to default free. However, Treasuries are an order of magnitude more liquid than Baas, so that the spread also contains a substantial liquidity premium. We discuss estimates using both the Baa-Aaa regression and the Baa-Treasury regression.

a. Estimates for QE1

Gagnon, et. al, (2010) report that in 10-year equivalents the Fed had purchased $169bn of Treasuries, $59bn of Agency debt, and $573bn of Agency MBS by Feb 1, 2010. The total purchase up to this date was $1.625tn and the anticipated total was $1.725tn. We scale up the numbers up to Feb 1, 2010 by 1.725/1.625 to evaluate the effect of the total purchase.

Agency debt and Treasury debt are equally safe during the QE period, while Agency MBS carries prepayment risk. Thus, if we consider only the Treasuries and Agencies purchased, and ask what effect this will have on the Baa-Aaa spread using the regression coefficient of -0.31, we find that the effect is 4 bps (we also use the fact that the end of 2008 LONG-SUPPLY/GDP = 0.140 for this computation). As we have noted, this is smaller than the true safety effect because Aaa corporate bonds are not as safe as either Agencies or Treasuries. As an upper bound, even if we use the Baa-Treasury coefficient (which includes a liquidity premium), the estimate is 11 bps. Although the event study may not identify the precise economic impact of QE for reasons we have discussed earlier, our regression estimates still appear quite small.

However, we have neglected an important aspect of the crisis. The regressions coefficients are estimates of an "average" demand for safety; for evaluating QE we are more interested in the demand function as of the Fall of 2008 and Winter of 2009. It is likely that demand during the crisis was elevated relative to an average period. One way of seeing this is to note that the CDS-adjusted Baa spread minus the CDS-adjusted Aaa spread averages 1.87% in the sample from 11/25/08 to 3/23/09. This number is an estimate of the relative safety value of the Aaa bonds over the Baa bonds. We can also estimate the historical average safety premium by evaluating ln(LONG-SUPPLY/GDP) at the 2008 level and multiplying by the -0.31 coefficient. This computation yields 0.61%. That is, the safety premium over the QE period was roughly 3 times the average level. The larger effects obtained from the QE1 event study than the regression approach suggest that changes in Treasury supply have much larger impact on the safety premium in times of unusually high safety demand than they do in average times.

b. Estimates for QE2

In QE2, the Fed announced that it will purchase $600bn of Treasuries and rollover the maturing MBS into long-term Treasuries. We suggested earlier that the latter effect translates to a purchase of $220bn over the next year, and $176bn for the following year, if the policy was kept in place. For the sake of argument, let us suppose that the market expects the policy to be in place for only one year then the total effect is to purchase $820bn of Treasuries.

The impact of an $820bn Treasury purchase can have a large effect on safety premia. However, QE2 occurs during normalized market conditions, so that the -0.31 coefficient estimates are appropriate during this period. For example, as of 10/22/2010, the spread between Baa rates and Aaa rates was 107 bps and the spread between Aaa rates and the 20 year Treasury bond was 111 bps. Averages for 1919-2008 are: Baa-Aaa=118 bps and Aaa-Treasury=81 bps. Thus the premia during QE2 are large and similar to historical averages.

The $820bn of Treasuries translates to $511bn of 10-year equivalents, based on the planned maturity breakdown provided by the Federal Reserve Bank of New York.[17] The LONG-SUPPLY/GDP ratio at the end of 2009 was 0.165. Based on these numbers, using the -0.31 coefficient, we find that QE2 should increase the safety premium by 7 bps. Using the upper bound coefficient of -0.83, we estimate an effect of 21 bps.

5. Conclusion

We document that QE1 and QE2 significantly lower nominal interest rates on Treasuries, Agencies and highly-rated corporate bonds. There are several primary channels for these effects. QE increased the safety premium on low-default risk bonds substantially, driving the yields on such bonds down. We also find significant evidence for the signaling channel which drives down the yield on all bonds. In addition, QE increased expected inflation and generally implied larger reductions in real than in nominal rates. Furthermore, the impact of QE on MBS rates is large when QE involves MBS purchases (QE1), but not when it involves only Treasury purchases (QE2), indicating that another main channel for QE is to affect the equilibrium price of mortgage-specific risk.[18]

[17] http://www.newyorkfed.org/markets/lttreas_faq.html

[18] In the recent recession, QE has been undertaken by governments in both the US and UK. From the UK experience, Joyce, Lasoasa, Stevens, and Tong (2010) examine the effects of QE in the UK. As with QE2 in the US, the UK QE consisted of purchases of long-term government bonds (totaling 200 billion pounds). Joyce et.al. document that QE lead to large reductions in government bond yields, smaller effects on investment grade bonds and more erratic effects on non-investment grade corporate bonds. They find only small effects on derivatives measures of future policy rates (to capture the signaling effects). The authors do not consider the effects on CDS

The principal contribution of our work relative to prior work on QE in the US (D'Amico and King (2010), Gagnon, Raskin, Remache, and Sack (2010) and Hamilton and Wu (2010)) is that by analyzing the differential impact of QE on a host of interest rates, our findings shed light on the channels through which QE affects interest rates. Our results document that which interest rates will be affected the most depends crucially on which assets are purchased, with the most dramatic difference across QE1 and QE2 seen in the impact in MBS rates (and thus likely in household borrowing rates).

While the prior literature does not discuss the channels for QE in as much detail as we do, it points to the operation of QE through two main channels: the signaling channel as well as a "portfolio-balance channel." Relative to prior work, we have fleshed out the portfolio-balance channel in more detail. Brian Sack, the head of the Federal Reserve Bank of New York's Open Market Desk, describes the portfolio balance channel as follows:[19]

By purchasing a particular asset, the Fed reduces the amount of the security that the private sector holds, displacing some investors and reducing the holdings of others. In order for investors to be willing to make those adjustments, the expected return on the security has to fall. Put differently, the purchases bid up the price of the asset and hence lower its yield. These effects would be expected to spill over into other assets that are similar in nature, to the extent that investors are willing to substitute between the assets. These patterns describe what researchers often refer to as the portfolio balance channel.

In thinking about the portfolio balance channel, it is key to understand which assets are substitutes for those which the Fed purchases. We have considered specific finance-theory based versions of the portfolio-balance channel, each indicating how assets may substitute for others. One channel that emerges as substantial is that QE works through a safety channel affecting long and medium-term bonds. Investors have a unique demand for low-default-risk assets of particular maturities. When the Fed purchases a large quantity of such assets, investors bid up the price on the remaining low-default-risk assets, decreasing the yields on these assets. The

rates, inflation, or MBS rates. It would be interesting to revisit the UK QE evidence explicitly in the framework of our channels approach.

[19] See http://www.newyorkfed.org/newsevents/speeches/2009/sac091202.html.

safety channel highlights the substitutability of assets within a (low) default-risk class. In other words, the safety channel can be thought of as a preferred-habitat for particular maturities, but only applying to low-default-risk assets. Another type of portfolio-balance channel that has received much attention recently is the duration-risk channel. In this channel, QE has an effect on long-term rates by reducing the duration risk held by investors, and thereby reducing the term premium on longer term assets. Under the duration-risk channel, the key dimension of substitutability is duration. When the Fed removes duration from the portfolios of investors, the investors substitute by purchasing other long-duration assets to make up for the lost duration. Longer duration assets, which substitute better for the removed duration vis-à-vis short duration assets, fall the most in yield. We do not find support for the operation of the duration-risk channel. Instead, the role of duration appears to be through a preferred-habitat for particular maturities.

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Figure 1. Safety Premium on Bonds with Near-Zero Default Risk

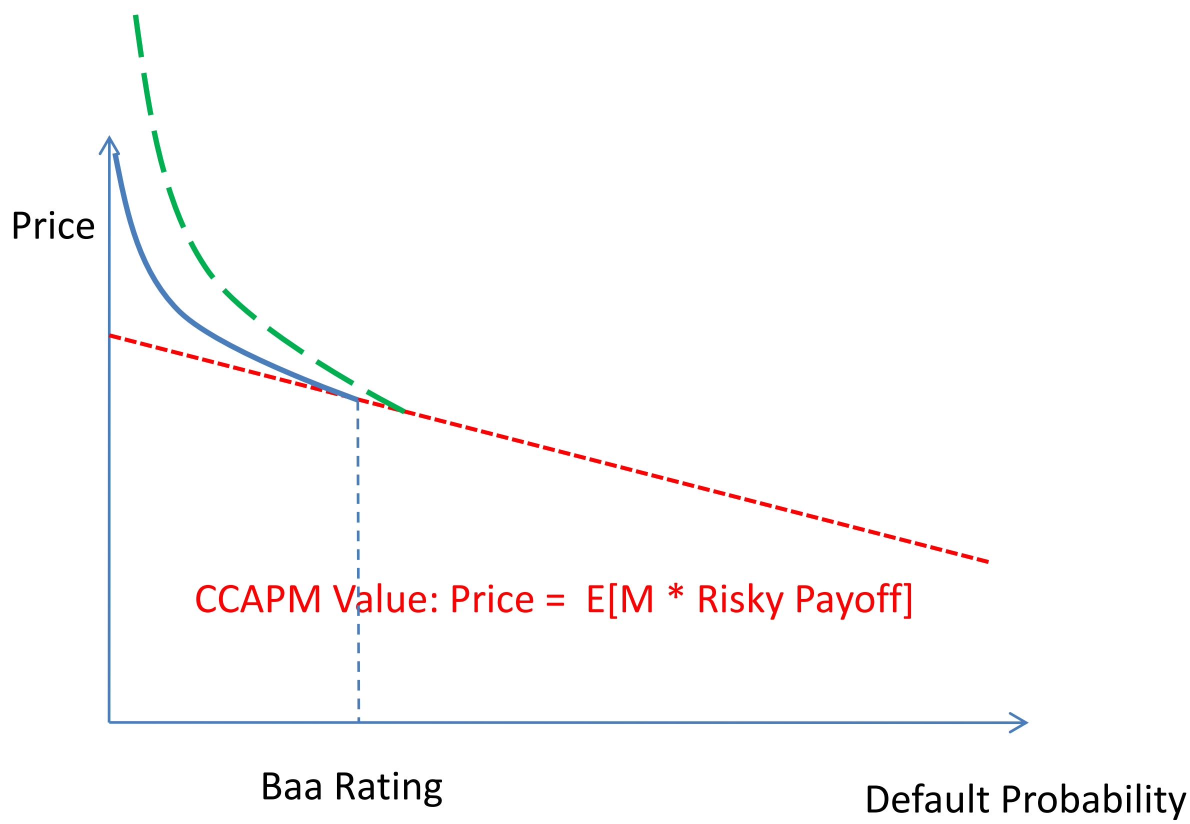
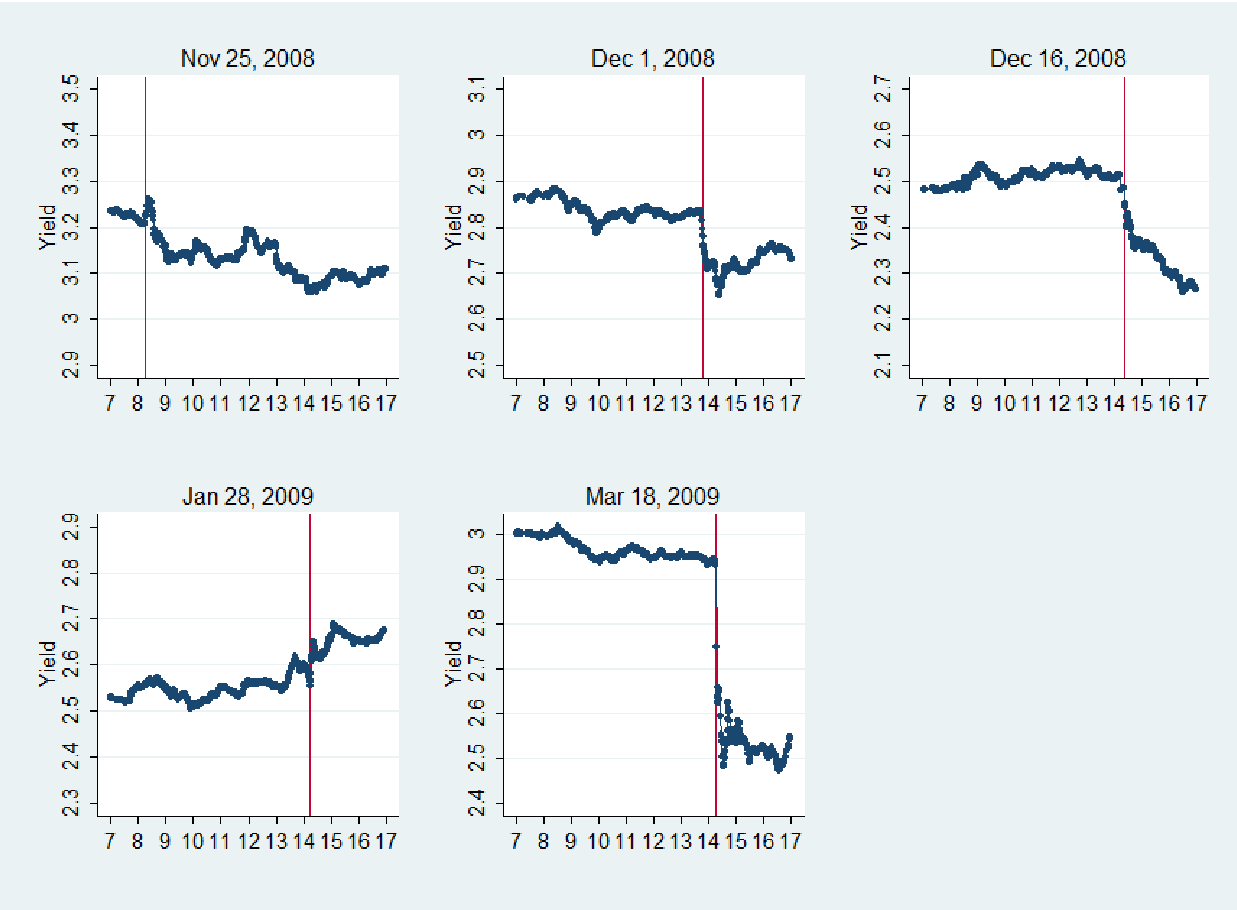
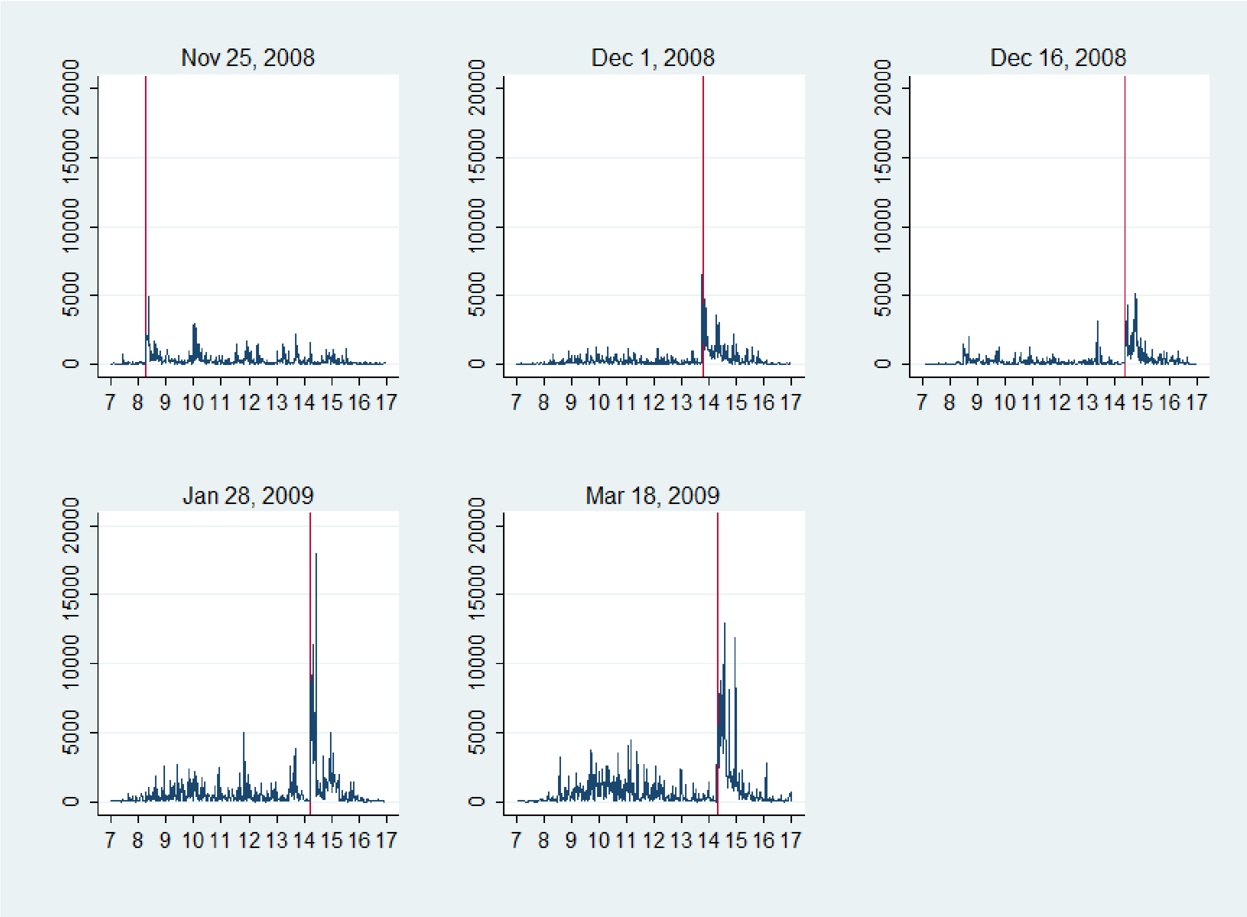


Figure 2. Intra-day Yields and Trading Volume on QE1 Event Days

Panel A. Yields

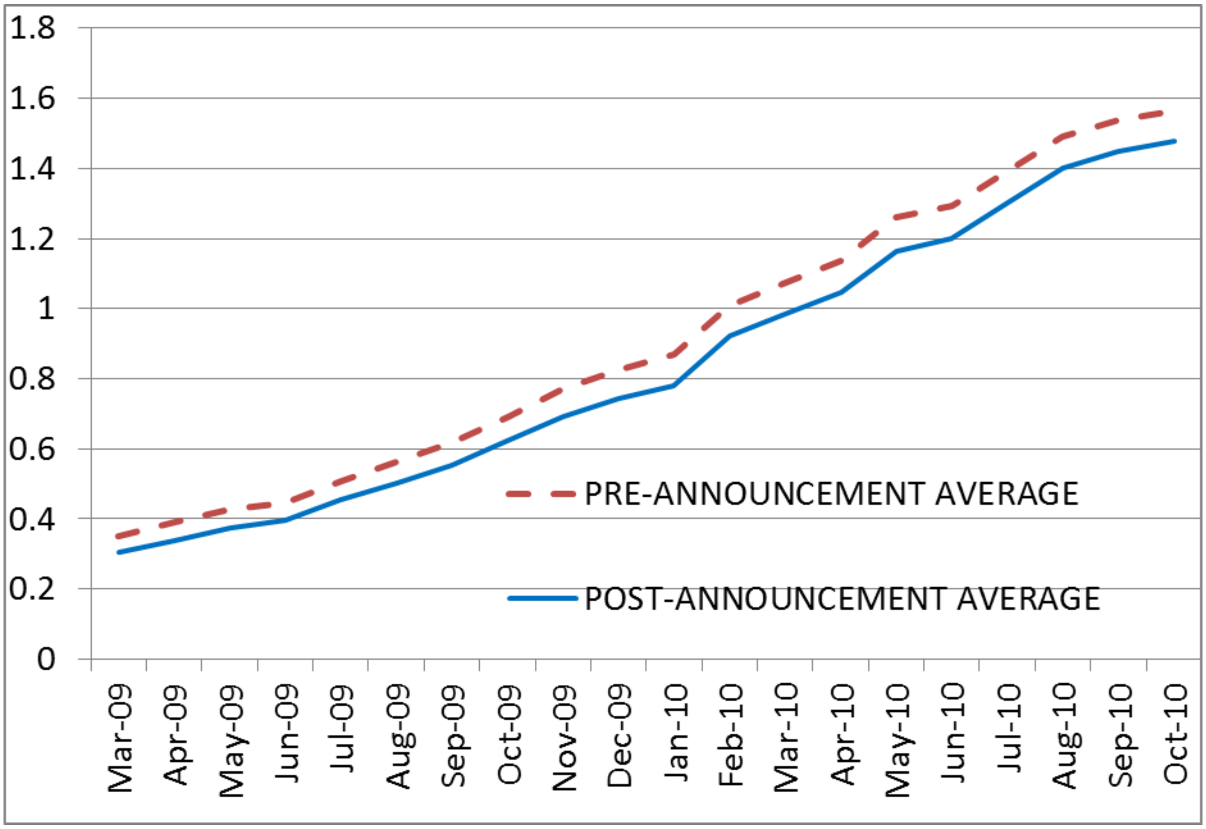


Panel B. Trading Volume



Note: This figure is based on data purchased from BG Cantor and the data graphed is for the on-the-run 10 year bond at each date. Yields graphed are averages by the minute and trading volume graphed is total volume by minute. The vertical lines indicate the minute of the announcement, defined as the minute of the first article covering the announcement in Factiva.

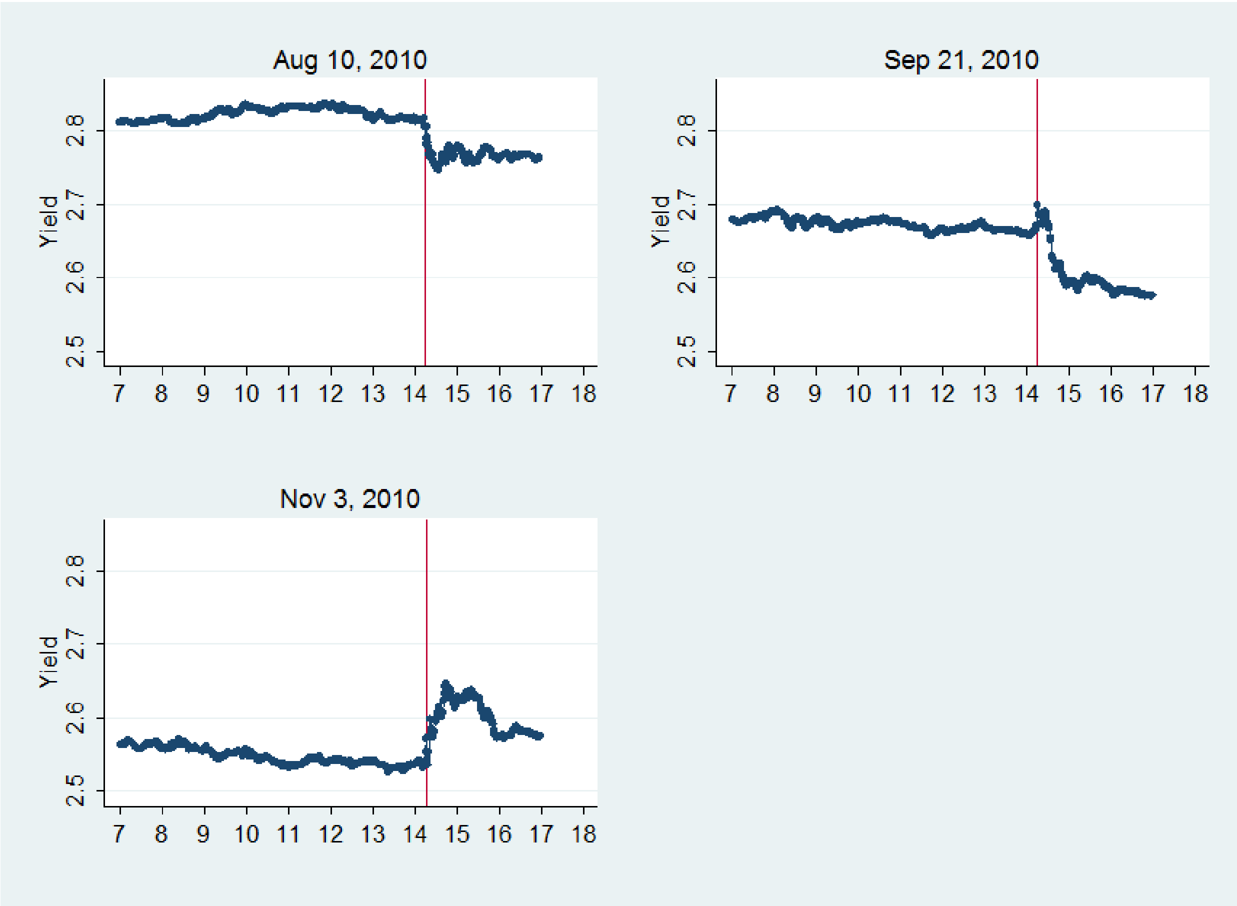
Figure 3. Yield Curves from Fed Funds Futures, pre- and post QE1 Event Days



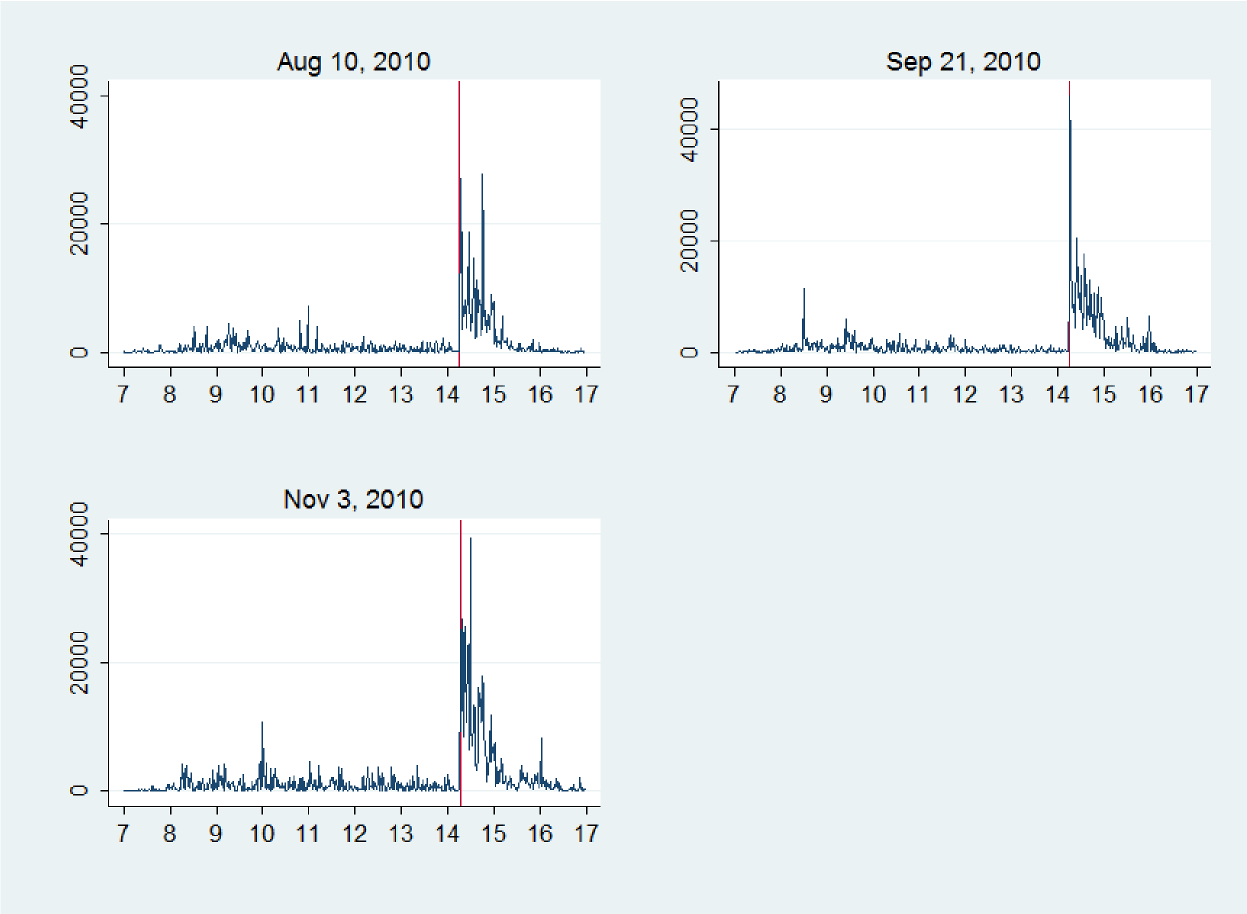
Note: The figure graphs the yields (in %) on the Federal Funds futures contract, by contract maturity. The yields are computed the day prior to the QE1 event dates and again the day after the event dates. All of the pre-event yields, and all of the post-event yields, are then averaged across events. All data are from Bloomberg.

Figure 4. Intra-day Yields and Trading Volume on QE2 Event Days

Panel A. Yields

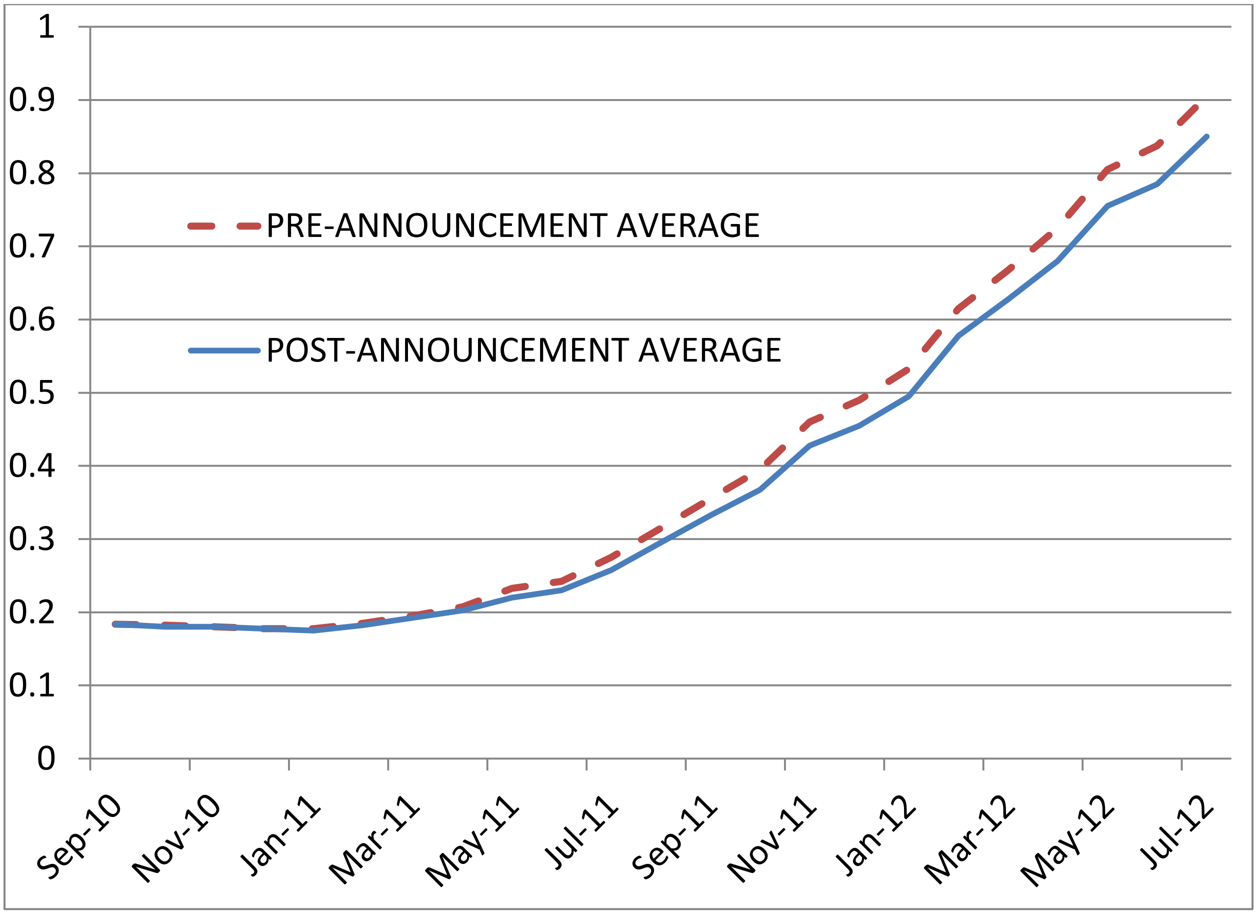


Panel B. Trading Volume



Note: See note to Figure 2.

Figure 5. Yield Curves from Fed Funds Futures, pre- and post QE2 Event Days



Note: The figure graphs the yields (in %) on the Federal Funds futures contract, by contract maturity. The yields are computed the day prior to the QE2 event dates and again at the end of the trading day of the event dates. All of the pre-event yields, and all of the post-event yields, are then averaged across events. All data are from Bloomberg.

Table 1. Treasury, Agency and Agency MBS yields on QE1 event dates

Two-day changes (in basis points)

Date	Event	Treasuries yields (constant maturity)					Agency yields			Agency MBS yields	
		30 year	10 year	5 year	3 year	1 year	10 year	5 year	3 year	30 year	15 year
11/25/2008	Initial announce-ment	-24	-36	-23	-15	-2	-76	-57	-42	-75	-147
12/1/2008	Bernanke speech	-27	-25	-28	-15	-13	-67	-50	-28	-10	58
12/16/2008	FOMC statement	-32	-33	-15	-4	-5	-39	-26	-28	-30	-7
1/28/2009	FOMC statement	31	28	28	19	4	28	27	16	6	16
3/18/2009	FOMC statement	-21	-41	-36	-24	-9	-45	-44	-38	-19	-18
Above 5 dates	Above 5 events	-73*	-107**	-74	-39	-25*	-199***	-150**	-120***	-128**	-98

Note: The Treasury yields are from FRED (the constant maturity series). The agency yields are for FNMA bonds and the MBS yields are for the current coupon GNMA. Both are from Bloomberg.

* denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level.

Table 2. Corporate Yields, and Corporate Yields Adjusted by CDS on QE1 Event Dates

Two-day changes (in basis points)

Corporate Yields

	Aaa long	Aa long	A long	Baa long	Ba long	B long	Aaa int	Aa int	A int	Baa int	Ba int	B int
11/25/2008	-28	-18	-23	-19	-4	4	-17	-15	-18	-18	1	-47
12/1/2008	-24	-24	-21	-17	-13	28	-21	-15	-18	-8	-5	6
12/16/2008	-43	-37	-45	-39	1	-11	-19	-21	-24	-27	-28	-42
1/28/2009	34	17	17	14	-16	-25	12	8	7	3	-32	-25
3/18/2009	-16	-21	-21	-20	-28	-39	-43	-50	-39	-26	-18	-22
Above 5 dates	-77	-83**	-93**	-81**	-60**	-43	-88**	-93**	-92**	-76**	-82***	-130***

	Credit Default Swaps (10 year maturity)						Credit Default Swaps (5 year maturity)					
	Aaa	Aa	A	Baa	Ba	B	Aaa	Aa	A	Baa	Ba	B
11/25/2008	-3	8	-12	-15	-65	-464	-3	-5	-14	-14	-58	-353
12/1/2008	4	0	7	9	52	-175	3	2	10	5	52	-138
12/16/2008	-4	-8	-17	-20	-23	-83	-4	-15	-17	-25	-31	-22
1/28/2009	-8	-17	-6	-13	-28	-25	-6	-9	-9	-11	-21	-33
3/18/2009	-3	1	11	-9	-20	-20	-3	8	18	-12	-24	-21
Above 5 dates	-15	-16	-16	-48	-84	-768	-13	-19	-11	-56	-82	-568

Corporate Yields-Credit Default Swaps

	Aaa long	Aa long	A long	Baa long	Ba long	B long	Aaa int	Aa int	A int	Baa int	Ba int	B int
11/25/2008	-25	-26	-11	-4	61	468	-14	-10	-4	-4	59	306
12/1/2008	-28	-24	-28	-26	-65	203	-24	-17	-28	-13	-57	144
12/16/2008	-39	-29	-28	-19	24	72	-15	-6	-7	-2	3	-20
1/28/2009	42	34	23	27	12	0	18	17	16	14	-11	8
3/18/2009	-13	-22	-32	-11	-8	-19	-40	-58	-57	-14	6	-1
Above 5 dates	-63	-67	-76	-33	24	724	-75	-74	-80	-19	0	437

Note: The corporate yield indices are from Barclay's and downloaded from Datastream. The CDS rates by ratings are constructed from data from CMA and downloaded from Datastream, and using ratings from FISD, and information needed to calculated value-weighted averages obtained from FISD (issue sizes) and TRACE (prices). * denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level. Significance levels for results involving CDS rates to be added in next version.

Table 3. Inflation Swaps, TIPS, and Implied Interest Rate Volatility on QE1 Event Dates

Two-day changes (in basis points)

Date	Event	Inflation swaps				TIPS real yields (constant maturity)			Interest rate volatility
		30 year	10 year	5 year	1 year	20 year	10 year	5 year	
11/25/2008	Initial Announcement	1	-6	-28	48	-22	-43	5	1
12/1/2008	Bernanke speech	15	27	11	-40	-38	-34	-51[20]	-7
12/16/2008	FOMC Statement	4	37	35	-17	-45	-57	-83	-20
1/28/2009	FOMC Statement	14	15	-6	5	15	6	13	0
3/18/2009	FOMC Statement	2	22	24	45	-45	-59	-43	-11
Above 5 dates	Above 5 events	36**	95**	36	41	-135***	-187***	-144***	-37***

Note: Inflation swap rates and interest rate volatility (ticker BBOX) is from Bloomberg. TIPS yields are from FRED. * denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level.

[20] The constant maturity TIPS data from the Federal Reserve website indicates that the 5 year TIPS fell by 244 bps on the 12/1/2008 event. We think this is a data error. We examined the yield movements in the underlying TIPS bonds, with maturities ranging from 2013 to 2015. These bonds change in yield from -39 bps to -58 bps, with an average change of -51 bps. We report the -51 bps number in the table.

Table 4. Federal Funds Futures Yields over QE1 and QE2 Event Dates

One and two-day changes (in basis points)

	QE1 (5 events)		QE2 (8/10 and 9/21)	
Contract Maturity	1-day	2-day	1-day	2-day
3rd month	-26.5*	-27.5*	0	0
6th month	-26.5*	-27	-0.5	-0.5*
12th month	-36.5***	-33**	-4***	-5**
24th month	-59***	-40	-11***	-16***

Note: All data are from Bloomberg. * denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level.

Table 5. Treasury, Agency and Agency MBS Yields on QE2 Event Dates

One and two-day changes (in basis points)

Date	Event	Changes	Treasuries yields (constant maturity)					Agency yields		Agency MBS yields	
			30 year	10 year	5 year	3 year	1 year	10 year	5 year	30 year	15 year
8/10/2010	FOMC meeting	1-day	-1	-7	-8	-3	-1	-7	-9	1	-5
		2-day	-8	-14	-10	-3	-1	-13	-9	-8	-4
9/21/2010	FOMC meeting	1-day	-8	-11	-9	-5	0	-11	-9	-7	1
		2-day	-13	-16	-10	-5	-1	-16	-10	4	5
11/3/2010	FOMC meeting	1-day	16	4	-4	-2	0	5	-5	-5	-2
		2-day	11	-10	-11	-6	-1	-10	-14	-13	-3
8/10 and 9/21		1-day	-9*	-18***	-17***	-8***	-1	-18***	-18***	-6	-4
		2-day	-21***	-30***	-20***	-8***	-2	-29***	-19***	-4	1

Note: Data sources are as for QE1. * denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level.

Table 6. Corporate Yields, and Corporate Yields Adjusted by CDS on QE2 Event Dates

One and two-day changes (in basis points)

Date	Change	Corporate Yields: Aaa long	Aa long	A long	Baa long	Ba long	B lng	Aaa int	Aa int	A int	Baa int	Ba int	B int
08/10/2010	1-day	0	3	1	1	-3	-9	-4	-2	-2	-3	0	6
	2-day	-10	-5	-7	-7	-3	-5	-8	-5	-6	-6	9	23
9/21/2010	1-day	-9	-9	-9	-8	-7	2	-9	-9	-10	-10	-4	-3
	2-day	-13	-12	-13	-11	-15	1	-10	-8	-10	-11	-3	2
11/3/2010	1-day	10	11	12	9	28	-1	-2	-2	-1	-1	-1	-5
	2-day	5	2	4	-1	22	-10	-10	-11	-13	-14	-12	-18
8/10 and 9/21	1-day	-9	-6	-8	-7	-10***	-7	-13***	-11**	-12*	-13**	-4	3
	2-day	-23***	-17*	-20***	-18**	-18***	-4	-18***	-13**	-16**	-17***	6	25**

Date	Change	Credit Default Swaps (10 year maturity): Aaa	Aa	A	Baa	Ba	B	Credit Default Swaps (5 year maturity): Aaa	Aa	A	Baa	Ba	B
08/10/2010	1-day	0	6	1	1	5	13	1	6	2	4	8	9
	2-day	1	12	4	8	15	29	1	17	4	10	21	30
9/21/2010	1-day	2	-3	1	0	1	8	-1	-1	1	0	3	11
	2-day	2	1	2	2	9	20	0	4	2	2	8	26
11/3/2010	1-day			No data						No data			
	2-day												
8/10 and 9/21	1-day	2	3	2	1	6	21	0	5	2	4	11	20
	2-day	3	13	6	10	24	49	2	20	6	13	30	56

Date	Change	Corporate Yields-Credit Default Swaps: Aaa long	Aa long	A long	Baa long	Ba long	B long	Aaa int	Aa int	A int	Baa int	Ba int	B int
08/10/2010	1-day	0	-3	0	0	-8	-22	-5	-8	-4	-7	-8	-3
	2-day	-11	-17	-11	-15	-18	-34	-9	-22	-10	-16	-12	-7
9/21/2010	1-day	-11	-6	-10	-8	-8	-6	-8	-8	-11	-10	-7	-14
	2-day	-15	-13	-15	-13	-24	-19	-10	-12	-12	-13	-11	-24
11/3/2010	1-day			No data						No data			
	2-day												
8/10 and 9/21	1-day	-11	-9	-10	-8	-16	-28	-13	-16	-14	-17	-15	-17
	2-day	-26	-30	-26	-28	-42	-53	-20	-33	-22	-30	-24	-31

Note: The corporate yield indices are from Barclay's and downloaded from Datastream. The CDS rates by ratings are constructed from data from CMA and downloaded from Datastream, and using ratings from FISD, and information needed to calculated value-weighted averages obtained from FISD (issue sizes) and TRACE (prices). * denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level. Significance levels for results involving CDS rates to be added in next version.

Table 8. Inflation Swaps, TIPS, and Implied Interest Rate Volatility on QE2 Event Dates

One and two-day changes (in basis points)

Date	Event	Changes	Inflation swaps				TIPS real yields (constant maturity)			10 year interest rate volatility
			30 year	10 year	5 year	1 year	20 year	10 year	5 year	
8/10/2010	FOMC meeting	1-day	5	-1	-3	0	-10	-9	-8	-2
		2-day	-2	0	-3	-4	-6	-9	-5	-3
9/21/2010	FOMC meeting	1-day	6	6	6	-1	-14	-16	-14	-1
		2-day	6	4	7	9	-17	-20	-18	-2
11/3/2010	FOMC meeting	1-day	6	-3	2	1	4	1	-6	-2
		2-day	1	-10	4	14	2	-5	-14	-3
8/10 and 9/21		1-day	11***	5	3	-1	-24***	-25***	-22***	-3***
		2-day	4	4	4	5	-23***	-29***	-23***	-5***

Note: Data sources are as for QE1. * denotes significance at 10% level, ** denotes significance at 5% level and *** denotes significance at 1% level.