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The effect of quantitative easing on long-term interest rates

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THE EFFECT OF QUANTITATIVE EASING ON LONG-TERM INTEREST RATES

By

Lance Vought

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Supervising Instructor (Print Name and have signed)

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Eastern Michigan University

Economics Department

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April 2011

Abstract

In December 2008, with the target Fed Funds rate at a zero lower bound, the Federal Reserve had to use an unprecedented monetary policy tool known as quantitative easing to help stimulate the economy and achieve economic goals. This paper will explain what quantitative easing is, why it became necessary and how it has been implemented. In this paper, we will discuss prior literature from Federal Reserve staff economists on the fluctuation of long-term interest rates in response to these quantitative easing policies. The paper will conclude with an ordinary least squares regression analysis using United States economic data to try and explain the marginal effect of quantitative easing on various long-term rates. Our model indicates that to this point, quantitative easing was successful in lowering mortgage rates, but its impact on Treasury rates is statistically insignificant.

What is Quantitative Easing?

Quantitative easing, also known as a large scale asset purchase, is a substantial purchase of securities by a central bank in the hopes of achieving set economic targets when adjusting short-term interest rates is not feasible. Before the United States' implementation of such a policy in 2009, the primary prior use of it was by the Bank of Japan, which has been engaging in easing since 1999. When a central bank's normal expansionary monetary policy tool of adjusting short-term overnight lending rates (in the United States it is the Fed Funds rate) is at a zero bound, they are unable to adjust it to expand economic activity. Instead, the central bank targets long-term interest rates and attempts to lower the yields on long-term assets to create an incentive for businesses to undertake capital spending projects now and ultimately stimulate the economy. To be clear, the zero bound is not where interest rates are specifically at 0 percent. The Federal Reserve, along with other central banks, maintains their boundaries between a lower bound of 0 basis points and an upper bound of 25 basis points. The Fed has undertaken two rounds of quantitative easing during the 2007-09 recession and its aftermath. The goal of this paper is to test whether quantitative easing has had the desired impact of lowering long-term rates.

Normally, the main monetary policy tool a central bank uses to achieve its economic goals is to change its target short term rates or overnight bank lending rates. Specifically in the United States, the main rate the Federal Reserve would normally target is the Fed Funds rate. This is done by engaging in open market operations—buying and selling government securities, primarily at short maturities, to maintain the rate at the proposed target Fed Funds level. However, in December 2008, the FOMC dropped the Fed Funds rate to a level of 0 to 25 basis points and it has maintained that level ever since. Since the target rate cannot fall below zero, the

Fed's main policy tool was constrained. In order to stimulate the economy, they had to use a different tool. The Fed decided to engage in quantitative easing. By doing this, it would in essence lower the yield on longer term securities and hopefully encourage investors to invest in shorter term assets and spend now rather than later. Additionally, it encourages banks to lend instead of sitting on excess reserves assuming capital requirements are not an issue.

In the first round of quantitative easing, the Federal Reserve purchased mortgage-backed securities and agency debt to help stimulate the economy and aid the struggling housing sector, which was the largest contributor to the most recent recession. In addition to liquidity programs and facilities being operated by the Fed, these purchases led to a massive expansion of the Fed's balance sheet from \$900 billion in August 2008 to over \$2.3 trillion, which is a cause for concern by members of the Federal Open Market Committee (FOMC) moving forward. In spite of this concern of an abnormally large balance sheet due to continued slack in the economy and low inflation, the FOMC enacted a second large scale asset purchase in November 2010.

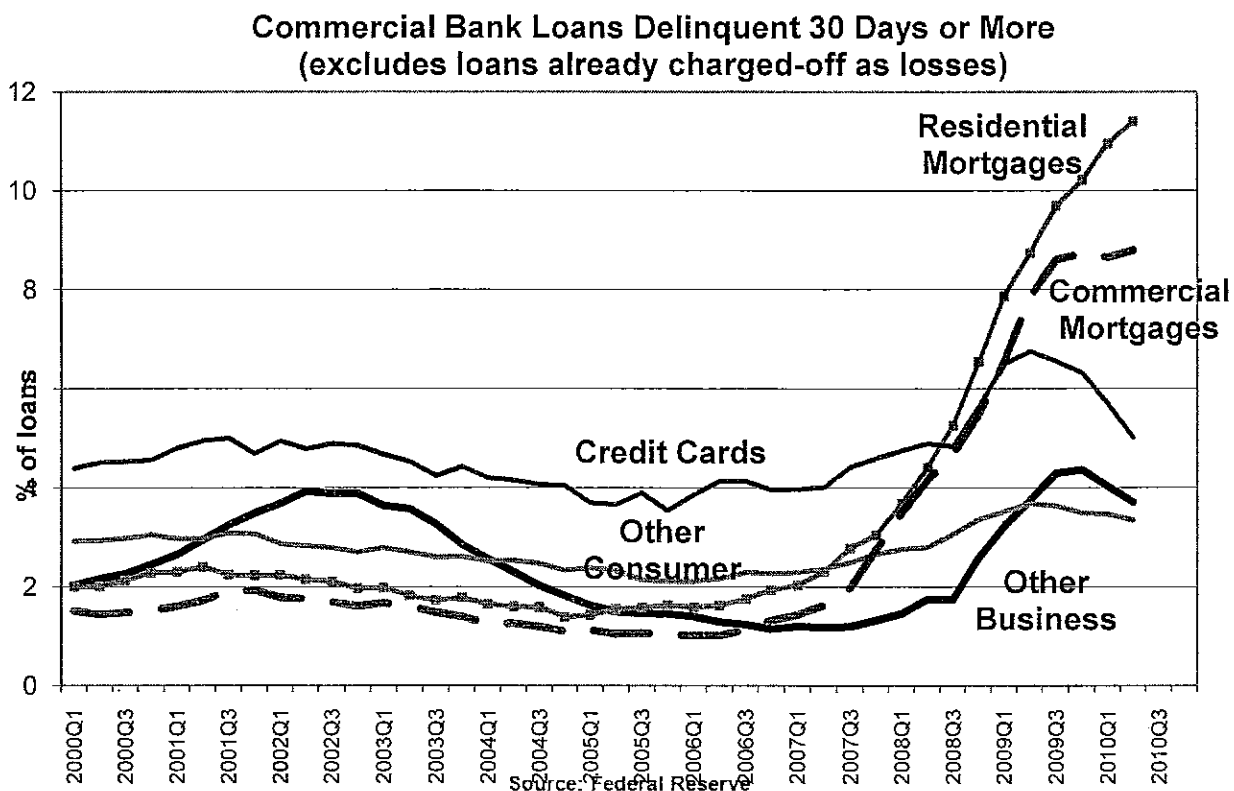
Historical Review—What Made Quantitative Easing Necessary?

To understand how the United States got into a situation where quantitative easing was necessary, we must take a look at the background of our most recent recession. August 2007 is documented as the supposed “bust” of the housing bubble in the United States¹. Interest rates began to rise and those with subprime, adjustable-rate mortgages began to default at abnormally high levels as indicated in Graph 1. This is due to their home-buyers' rates being reset much higher than what they could afford or were “teased” into an artificially low rate at the

¹ A post by economist Paul Krugman on his New York Times blog that announced the burst of the U.S. housing bubble just a week prior to the beginning of August can be found at:
<http://krugman.blogs.nytimes.com/2007/07/27/the-housing-bubble-has-burst/>

introduction of their loan. As a result, banks began to take severe hits of having to swallow the losses of defaulted loans and buying back foreclosed homes.

Graph 1:



According to the National Bureau of Economic Research (NBER)², the recession began in December 2007 and lasted through June 2009. Compared to past recessions, the most recent one has seen the most severe decline in GDP and its components, along with the most severe post-World War II increase in unemployment. The gap between the Non-Accelerating Inflation Rate of Unemployment (NAIRU) and unemployment reached unprecedented width and still remains at a significantly wide margin (around 4%).

March 2008 brought the fall of Bear Stearns investment bank. The collapse of such an established financial institution shook the foundation of the domestic economy. Bear Stearns was

² The NBER announcement of the peak in economic activity in December 2007 initiating the 2007-09 recession can be found here: <http://www.nber.org/cycles/dec2008.pdf>

saved and bought out by JP Morgan/Chase with government subsidies, but the haymaker was landed, and the economy was one hit away from being down for the count. Over the summer, the economy was on the verge of collapse and needed one last blow to knock it over as oil prices surged to unprecedented heights. Meanwhile, Americans struggled to pay off lines of credit and house loans with dwindling wealth and rising inflation.

September 2008 was that knockout blow with the collapse of Lehman Brothers, another one of the top financial institutions in the nation. It showed that even the “too big to fail” companies, can indeed fail. Lehman filed for Chapter 7 bankruptcy protection, and instead of the US government finding a suitor to bail them out like Bear Sterns, they let it fail. This set off a chain reaction of plummeting stocks, more failing banks and a deep recession, that took nearly two years to escape. These financial institutions were victim to poor or lackadaisical rating systems. Additionally, the banks that were engaging in multiple commerce areas due to the repeal of the Glass-Steagall act in 1999 participated in “storefront window lending,” giving out subprime loans to many unqualified suitors. In fact, the “NINJA” loans came to prominence in the bubble that led to the crisis. A “no income, no job, no assets” suitor would still qualify for a loan on a home for little or no down payment³.

Another contributor to the massive recession was the price shocks on commodities, specifically oil. Oil prices shot up in the summer of 2008 from approximately \$60-\$90 a barrel, to a peak of \$140 a barrel in July of 2008. Currently, oil is fluctuating between 95 and 100 dollars per barrel and was as low as \$30 per barrel in the spring of 2009. The oil price shock limited supply and sent prices on gasoline soaring to above an average of \$4 per gallon. As the financial markets became weak due to foreclosures and delinquencies in credit, Americans not

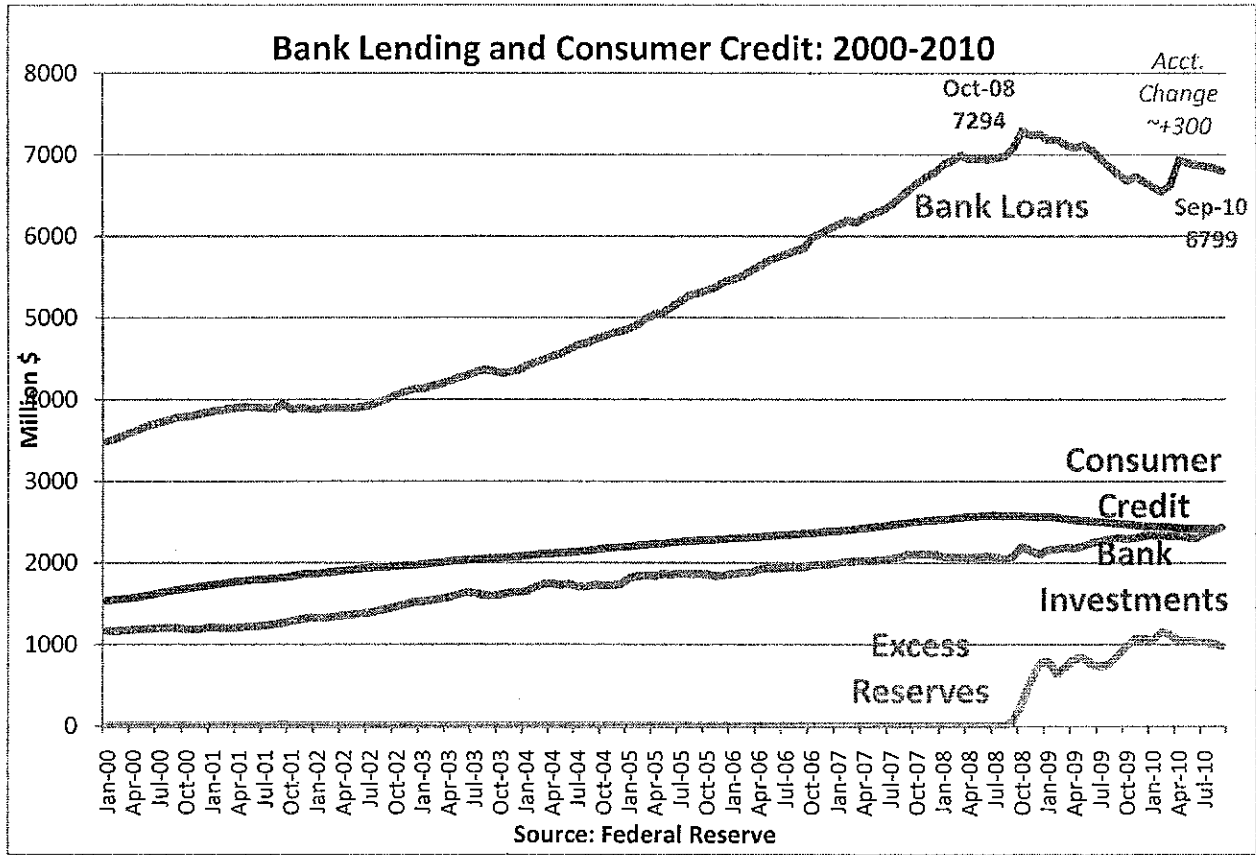
³ Report by the UK Paper *The Telegraph* on NINJA loans:
<http://www.telegraph.co.uk/finance/economics/2785403/Ninja-loans-explode-on-sub-prime-frontline.html>

only were trying to pay off their outstanding debts, but lived by allocating more money to gasoline in order to commute to their jobs or travel to purchase groceries or complete other necessary tasks. This chain reaction due to the oil price shock also sent inflation soaring, as price hikes in most goods and services were seen in the late summer of 2008. Currently inflation is below normal levels, in fact it is projected that we currently have continued low inflation levels despite oil prices and other commodities on the rise once again, due to such downward inflationary pressure in all other aspects of the economy.

The \$150 billion Fiscal Stimulus bill enacted in early 2008 by Congress under the George W. Bush administration allowed for working adults to receive \$600 in stimulus money, while married couples could receive \$1200 in stimulus money. The goal of this program was for consumers to take this money and spend it on goods and services to help stimulate growth in the economy by increasing domestic consumption. Unfortunately, most consumers took much of this increase in disposable income and used it to pay down debt (an aspect of savings), or saved it for future use, which is essentially what banks have been doing as well with their excess funds⁴. Instead of spending or lending, banks and households were saving the additional funds, and essentially putting a tightening stranglehold on consumption and slowing it down. However, in the past year, consumption has begun to rise again. Graph 2 indicates how excess reserves inflated in relation to the increased credit in the market instead of inducing additional bank lending. However, the stimulus plan did increase consumption somewhat, since many younger consumers that had no debt or had less incentive to save did use the money to consume, which could explain the discrepancy between the NBER peak and the GDP growth in the second quarter of 2008, which was the subsequent period after the enactment of the stimulus plan.

⁴ According to the Wharton School of Business at Penn, the average amount of 2008 fiscal stimulus money spent was 52%. The study can be found at: <http://finance.wharton.upenn.edu/~souleles/research/papers/PSJM2011.pdf>

Graph 2:

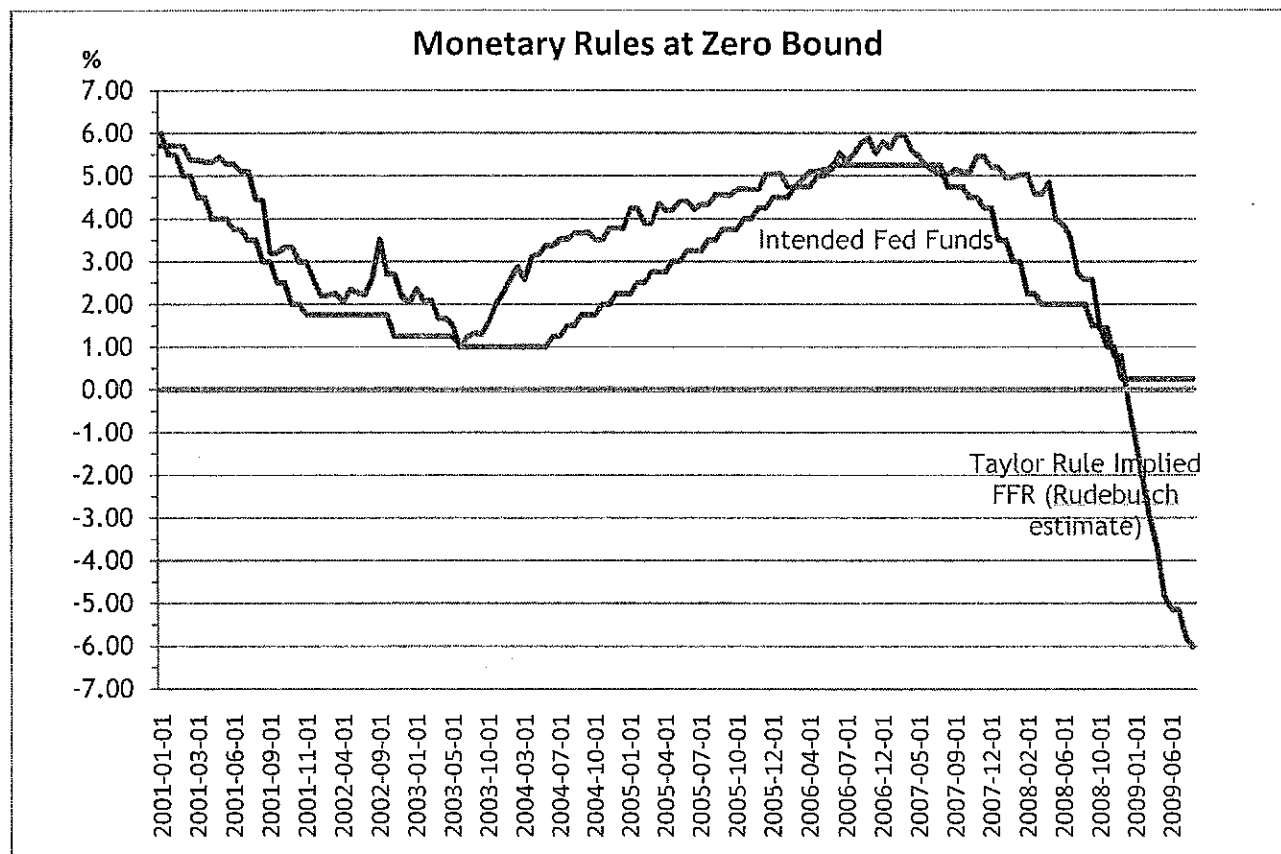


As mentioned previously, the Fed Funds rate has dwindled from 5.25% down to its current rate of 0 to 25 basis points in December 2008 and has remained there ever since. To try and keep the Fed Funds rate towards the upper bound of the target range, the Fed is currently paying 25 basis points on excess reserves. However, this was when the Federal Reserve had to implement quantitative easing to help stimulate the economy instead of targeting their short-term interest rates. To further identify the fact that interest rate changes cannot be used at this moment in time, which forced the Fed to utilize another monetary policy tool such as a large scale asset purchase, we calculate the target interest rate using the Taylor Rule, Rudebusch modification.⁵ Through 2009, as indicated by Graph 3, the Rudebusch modification of the Taylor Rule

⁵ Rudebusch (2001) creates a variation on the Taylor Rule, established in 1992, that accounts for uncertainty to analyze monetary policy decisions by the Fed to see if they were appropriate at the time.

suggested that the optimal Fed Funds rate was well below zero, indicated that no tightening of the Fed Funds was necessary at that time or the foreseeable future.

Graph 3:



According to the Rudebusch-modified Taylor Rule, the target Fed Funds rate to improve the economy and decrease unemployment is still well below zero. Since it is prohibitive to go below zero, we are unable to lower rates anymore than they currently stand. Lowering rates below zero would mean banks would have to charge for saving, which is counter-intuitive to do since the marginal propensity to save in the United States is currently around 5% due in part to a decline in consumption in response to decreased wealth.

The first round of quantitative easing (QE1) initiated by the Fed⁶ was to purchase agency debt and mortgage-back securities, in order to extend credit back into the market. The first program began in January of 2009 and ran through March of 2010, and in its entirety, led to a purchase of \$1.25 trillion in mortgage-backed securities, \$170 billion in agency debt and \$300 billion on Treasury securities. In addition, the Fed has paid 25 basis points in interest on excess reserves and other reserves held in the Fed's vault, which is one of the causes of the influx of excess reserves as indicated in Graph 1. The process of acquiring mortgage-backed securities was an attempt to stabilize the housing sector and pump liquid assets into the market to increase consumption again and increase output, by lowering the yields on longer-term assets. Meanwhile, the Fed was trying to get the unsafe mortgage-backed securities off the market. The increase in the monetary base from QE1 did not lead to a corresponding influx in the money supply, meaning that inflationary pressures remained low throughout the first round of asset purchases. This continues to concern inflation hawks though. Economists such as James Bullard that although inflationary pressures are currently low, any increase in inflation may not be able to be slowed or stopped once in motion due to the markets being saturated with liquidity, which can ultimately lead to hyperinflation. Additionally, he believes food and energy should be included in Fed targets to get a better estimate of how the economy is reacting to the asset purchases.⁷ However, due to such a weak economy and high unemployment, Bullard's concern is not widely supported at this point. Other concerns that surround these practices are the lack of "quantitative rules" such as those in the Taylor Rule for determining interest rates and also the decreased value of the dollar and the untested ways of getting assets off of the Fed's balance sheet that has inflated from \$800 billion to \$2.3 trillion in the past two years.

⁶ December 2008 FOMC statement: <http://federalreserve.gov/newsevents/press/monetary/20081230b.htm>

⁷ A recent Reuters article explaining Bullard's stance on inflation in the United States: <http://www.reuters.com/article/2011/04/18/us-usa-fed-bullard-idUSTRE73H44A20110418>

Unemployment soared in the most recent recession, increasing from 4.9%, all the way to 10.2% in November of 2009, its highest level since early 1983. This was not far behind the record high of post-WWII unemployment of 10.8%, which was infamously achieved in November of 1982. In recent months, unemployment has still tracked right around 9% and currently stands just below 9%. One main aspect that has led to such a high unemployment rate in spite of the prior recessions is due to what is called a “job-loss recovery.” Many firms in order to cut back on expenditures slashed labor quickly. This led to increased profits over time for firms despite rising costs and weak economic times. However, this slashing of labor, hoped to have led to a quicker recovery, but the need for QE2 indicates that the rapid recovery that was hoped for did not come to fruition.

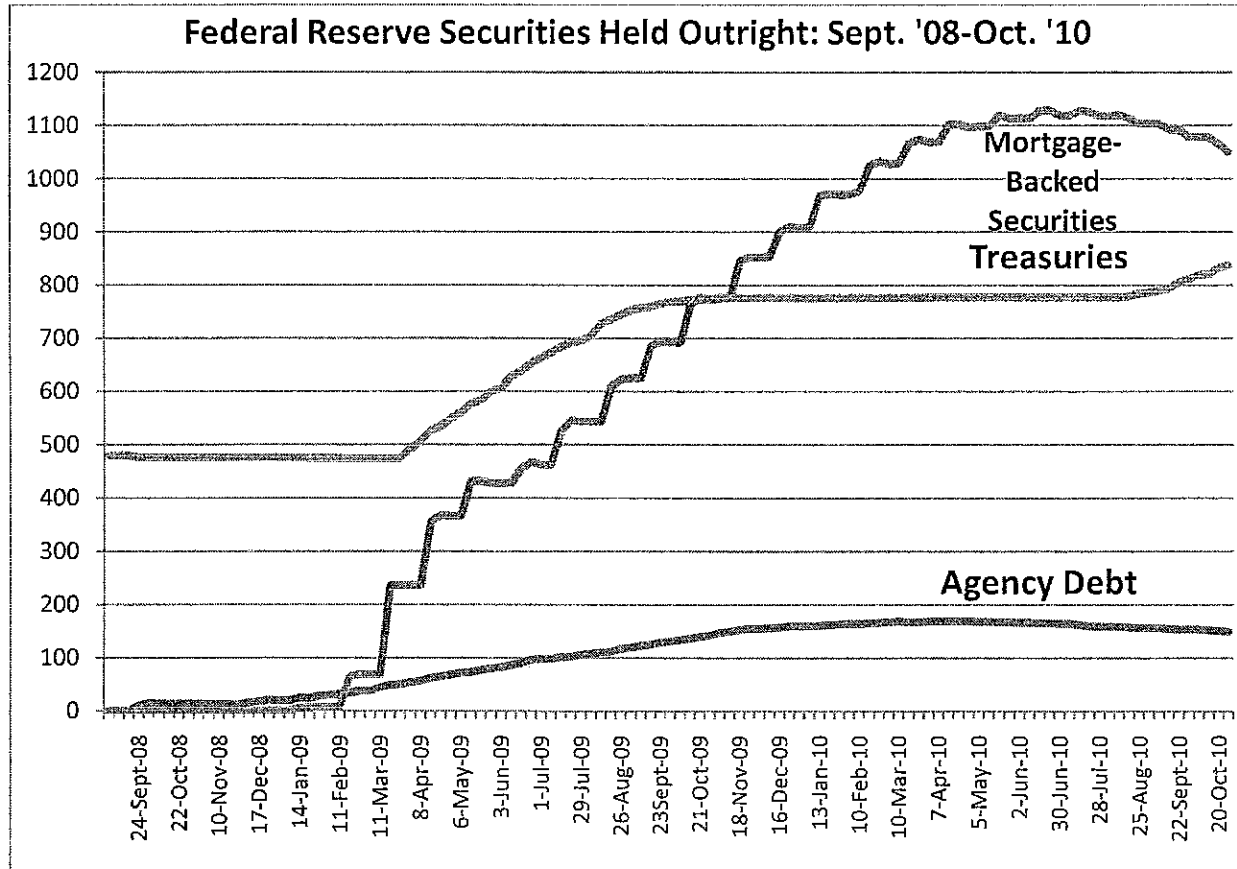
Due to the rapid principal payments and maturation of mortgage-backed securities through the summer of 2010, the Fed’s balance sheet was winding down at a faster than anticipated. In the meantime, the Fed maintained their standard practice of keeping the Fed Funds rate at 0 to 25 basis points. In August 2010, to avoid the balance sheet from shrinking any lower, the Fed decided to maintain the balance sheet at its current level and to reinvest the mortgage-backed securities’ principal payments in U.S. Treasury securities the subsequent month⁸. This is indicated by Graph 4. However, since the economic recovery was not continuing as hoped, in November 2010⁹, the Fed decided to begin a second large scale asset purchase, known as QE2. Instead of purchasing mortgage-backed securities and agency debt as in QE1, the Fed decided to purchase additional U.S. Treasury securities—mainly the large new

⁸ The August 2010 FOMC Statement announcing this reinvestment plan can be found here:
<http://federalreserve.gov/newsevents/press/monetary/20100810a.htm>

⁹ The November 2010 FOMC Statement announcing QE2 can be found here:
<http://federalreserve.gov/newsevents/press/monetary/20101103a.htm>

debt issues due to a large deficit—in excess of those already planned from the reinvested principal payments plan already enacted by the Fed.

Graph 4:



This asset purchase is \$600 billion in U.S. Treasury securities through June 2011. This leads to an average of \$75 billion in Treasury bills to be purchased by the System Open Market Account desk at the New York Federal Reserve Bank monthly from November 2010 through June 2011. Low inflationary pressures currently exist, but inflation could be quick to return due to excess liquidity in the markets and on the Fed's balance sheet, so a quick recovery, could be dangerous, although tightening too fast could lead to a double-dip recession by choking the recovery like in the early 1980's. There are pros and cons with quantitative easing, and since the U.S. has not operated at the zero bound before, these economic times are uncharted waters for us

all. The recession ended, but the danger did not pass. Decline may have ceased, but lack of confidence has not, as the University of Michigan Consumer sentiment survey suggests: the index is still tracking in the low 70's. The value of the dollar continues to fall, and with that brings concern of the movement away from the U.S. dollar as the world currency due to its volatility. There are many questions marks that need to be addressed as a result of this recession and quantitative easing. This paper however does not go into particular detail about the cascade of effects that quantitative easing has on the domestic and world economies, but will stick mainly to observing the effect of the asset purchases on long-term rates. Our overarching question is as follows: Does quantitative easing in fact lower long-term rates compared to what they would otherwise be without the purchases?

Review of the Literature

New York Fed economists Gagnon, Raskin, Remache and Sack (2010)¹⁰ analyzed whether or not the large scale purchase of mortgage-backed securities and agency debt in QE1 was effective. They based this on an analysis of lowering risk and term premiums and not short-term interest rate expectations. They explain that by lowering the expected return on the security (they do this by inflating the price of the asset) it discourages investors from purchasing longer term assets. As a result, it encourages businesses to undertake investment spending and invest in shorter term assets, which leads to short-term stimulation to the weak economy.

Gagnon, Raskin, Remache and Sack analyzed this by using an ordinary least squares regression of various indicators: cyclical indicators, supply indicators and uncertainty indicators. They felt that these would be the most relevant factors that influence term premiums and interest

¹⁰ Gagnon, Raskin, Remache, and Sack (2010): Large Scale Asset Purchases: Did They Work? Can be found at the following link: http://www.newyorkfed.org/research/staff_reports/sr441.pdf

rates and ultimately investment decisions. Their scope was to analyze term premiums while the scope of this paper is to analyze different interest rates, which indirectly addresses term premiums. Some of their variables and indicators are used in this paper's model, but some will be dropped or simplified to tailor it more for the regression analysis desired.

Aside from their own regression analysis, Gagnon et al. did not include expectations, because they felt that the only thing that affected the rates from an expectations standpoint was the announcements themselves, which came immediately before the asset purchases were to go into effect. Therefore, the rates or premiums due to announcements were not as drastic as they could have been had the Fed been less transparent in their discussions of monetary policy over the past three years. The only main period where there was a strong change in rates was after the initial announcement, which created much uncertainty since this was a new tool being implemented. Furthermore, since they only used a dataset that ranged from 1985-2008, the LSAP were not included in their sample. Instead, they were testing whether models estimated prior to the new program could effectively predict the impact of the program. In all, Gagnon et al. states that quantitative easing did do as it was intended, because not only did it lower rates on areas where the Fed's purchases were going (i.e. mortgage rates and the housing sector), but also lowered rates in other areas, such as government bonds.

Doh (2010) of the Kansas City Federal Reserve uses a preferred-habitat model rather than an expectations model, to suggest that asset purchases on a grand scale, such as the ones the Fed is currently engaging in, do in fact have an effect on long-term interest rates. Doh also suggests that the asset purchases themselves, given risk and uncertainty, are more effective than transparency and communication by the Federal Reserve stating that they will be making

purchases on this scale or maintaining low interest rates over a certain period (or as the FOMC Press releases state, “an extended period.”)

Doh states that the Fed’s rationale in purchasing long term assets, is to cut the supply of such assets, which will lead to an increase in the price (and thus a decrease in the bond yields). This would lead to a downward shift in the yield curve and, ultimately, declining long-term interest rates. Doh states that in the expectations model, changes in the supply of bonds do not matter since they are perfect substitutes for other assets and have flat demand curves. This is either due to the fact that the model considers investors risk-neutral, or that in spite of different interest rates, the risk the investor will bear will be the same independent of different interest yields on short and long-term assets.

Doh argues that with risk-averse investors and with certain markets preferring specific types of maturities, the demand curve for these assets is not flat. Given the amount of risk the investor intends to bear, demand could be moderately to extremely steep, but never flat. Given the fact that long-term assets are sensitive to fluctuations in short-term rates, there is a level of duration risk involved in holding longer term assets. As more of these long term assets are supplied to the market, the term premium increases. He concludes that because of these facts that the Fed’s quantitative easing policies in fact can have an effect on long-term interest rates.

According to Chung, Laforte, Reifschneider and Williams (2011), the goal of the large scale asset purchases was to lower long-term rates through three main channels. The first main channel was through transparency with the Fed’s stated commitment to keep the Fed Funds rate low for an extended period of time, more specifically at the zero bound. The second channel was to have an effect on the market in times of stress. The asset purchases allowed for yields to narrow due to lowered risk in the market, and ultimately a less stressful market would encourage

investors to spend now. The final channel is that the purchase of many of these securities lowers the overall supply in the market of these long-term securities. As Chung et al. states, by purchasing a significant proportion of the securities in the market, it leads to a reduced supply to others in the market for those securities. As supply is restricted, the price for the remaining securities rises, which will decrease the yield on the security. This would discourage investors from purchasing long-term assets since the yields are minimized and essentially manipulates them into buying short-term assets or undertake spending on investment projects. Chung et al. also adds that historically, a 2% cut in the Fed Funds rate would lead to a 50 basis point decline in the 10-year Treasury rates. Additionally, they state that the entire round of QE1 led to a 50 basis point decline in the 10-year Treasury rates. In the research presented below, we calculate and compare whether the results track similar to the Chung et al. estimates. Keep in mind, however, that the historical period for the former estimate was from 1987 through 2010, while the data in the regression analysis will be for a shorter period, starting in 1996.

Model

Gagnon, Raskin, Remache and Sack (2010), used a set of macroeconomic, uncertainty and supply variables to analyze the effect of the first round of large scale asset purchases on the term premiums of various long-term rates. They utilized unemployment gap, core inflation, long-run inflation disagreement, daily volatility on 10-year Treasury yields, and securities held by the public sector, by the Fed and by the foreign sector as variables to determine historical changes in the term premium. They, used an ordinary least squares regression (OLS) model to calculate their results:

$$tp_t^{10} = X_t\beta + \varepsilon_t$$

Where tp_t^{10} is the nominal 10-year yield term premium, and X_t is the aforementioned set of observable economic variables.

Using some of the variables suggested in the Gagnon model, I decided to construct a linear model for long term interest rates and as a result find the partial marginal effect of quantitative easing on those rates. I used OLS regression analysis to perform this as Gagnon, et al. did. The time series chosen for this model is from July 1996 through December 2010. Federal Reserve H4.1 data were used to construct two of the variables in the model and July 1996 was the earliest these data were available.¹¹ This provides an early enough starting point to show the effect of open market operations on long term rates before the presence of quantitative easing. December 2010 was the most recent data available at the time of completion of this analysis and encapsulates both the full first round of quantitative easing and the first two months of QE2. It is already anticipated that the numbers in this regression will be difficult to compare with previous interest rate fluctuations given the volatility in the economy during this time series. More contributory to this difficult comparison, though, is the fact that the amount of liquidity in the market and grand scale purchase of this magnitude was unprecedented in the history of the United States.

The dependent variables used are the following: 2-year Treasury bill, 5-year Treasury bill, 10-year Treasury bill, 30-year conventional mortgage rate, and the 15-year fixed mortgage rate. These rates were chosen since long-term Treasury rates are the usual long-term rates targeted by the Federal Reserve. When analysis of targeted long term rates is done, as seen is Chung et. al (2011), the 10-year Treasury Rate is used. Gagnon, et. al. in their model analysis, used the 2-year and 10-year Treasury rates. I chose to include the 5-year rate as an indicator

¹¹ H4.1: Factors Affecting Reserve Balances can be found on the Federal Reserve Board of Governors website at <http://federalreserve.gov/releases/h41/>

between the 2-year and 10-year maturities, since I figured that was too wide of a period to analyze long-term differential. Moving from 2-year to 5-year to 10-year, I anticipated to see a gradual reduction in the impact of quantitative easing from one to the next. I included the 30-year and 15-year mortgage rates as an indicator of the effect of mortgage-backed securities purchases on mortgage-specific interest rates. Since the bulk of QE1 was the purchasing of mortgage-backed securities, I felt that quantitative easing would have a more direct marginal effect on the mortgage rates than the Treasury rates. The other Fed papers analyzing the effects of quantitative easing do not include this as a dependent variable in their analysis, but I feel that it is something to consider, especially with the Fed being such a big player in the housing market during the first large scale asset purchases of QE1.

The independent variables included are the following: open market operations, quantitative easing, federal funds rate, unemployment gap, inflation, and market expectations. The data for the long-term interest rates, unemployment, federal funds rate, market expectations and inflation were acquired using the FRED database of the St. Louis Federal Reserve bank. Market expectations were determined by using the St. Louis Federal Reserve Financial Stress Index¹² values for each month. The St. Louis Financial Stress Index is calculated by applying 18 different market indicators into a predetermined regression function from past principal component analysis (PCA). The PCA eliminates the co-linearity issues that may be associated with variables that track similarly. The cumulative effect of all 18 of these indicators is the final value indicated by the stress index. A negative sign means that there is a decline in market stress; a positive sign indicates an increase in financial market stress. The data for quantitative easing and open market operations were found using the H4.1 balance sheet from the Board of

¹² The St. Louis Federal Reserve Financial Stress Index indicators and their coefficients can be found on the St. Louis Federal Reserve website at: <http://research.stlouisfed.org/publications/net/NETJan2010Appendix.pdf>

Governors and the System Open Market Account (SOMA) desk website of the New York Federal Reserve Bank.

The following is the regression function:

$$r_{it} = \beta_0 + \beta_1 \text{OMO} + \beta_2 \text{QE} + \beta_3 \text{FFR} + \beta_4 \text{URGAP} + \beta_5 \text{INFL} + \beta_6 \text{STL} + \varepsilon_t$$

The explanatory variables were derived as follows:

$$1) \text{ OMO} = ((X_t - X_{t-1}) / B_t) * 100$$

Where X_t is all Treasury securities held by the Federal Reserve in the last H4.1 of the current month, X_{t-1} is the securities held by the Federal Reserve in the last H4.1 of the previous month, and B_t is the St. Louis Federal Reserve measure of the monetary base of the current month. Open market operations is used in this regression, because we wanted to see the difference between the effect of regular security purchases by the Fed and the large scale asset purchases done over the past couple of years. We expected the sign on this variable to be negative, with an increase in open market operations lowering interest rates—the typical expansionary monetary policy tool used by the Fed.

$$2) \text{ QE} = ((A_t + M_t + T_t) / B_t) * 100$$

$A_t = (D_t - D_{t-1})$, where D_t is the agency debt held by the Federal Reserve in the last H4.1 of the current month, D_{t-1} is the agency debt held by the Federal Reserve in the last H4.1 of the previous month. M_t is the net purchase of mortgage-backed securities in the current month, and T_t is the number of treasury securities purchased as part of QE2 in the current month.

The types of purchases are aggregated due to the fact that Treasury securities have only been incorporated into QE in the four months of the time series, and MBS and agency debt have not been used after QE1. If we were to create three different variables to calculate their effect individually, it would be likely that, with the exception of mortgage-backed securities, they

would individually not have a statistically significant effect on the rates given the short length of the time series. This is the main explanatory variable we will be looking at to see the impact of quantitative easing on the selected long-term interest rates. The expected sign for the QE variable is to be negative. It would be expected that a significant purchase of securities or debt would lead to a drop in the long-term interest rates since it was the main goal of the large scale asset purchases.

3) $URGAP = (U_t - N_t)$

Where U_t is the unemployment rate in the current month, and N_t is the Non-Accelerating Inflation Rate of Unemployment (NAIRU) in the current month. Unemployment gap was included in the Gagnon model and is a main macroeconomic indicator which should be a strong explanatory variable for interest rates. The sign on this variable is expected to be negative; a widening in the gap between NAIRU and unemployment would indicate weak economic growth, which in basic monetary policy theory would lead to a decline in interest rates to help stimulate growth.

4) $INFL = ((P_t/P_{t-12}) - 1) * 100$

Where P_t is the core price index¹³ in the current month, P_{t-12} is the core price index of 12 months prior. Core inflation was another macroeconomic variable used in the Gagnon model that seemed appropriate to replicate in our model due to its strong correlation with changes in interest rates. The expected sign on core inflation should be positive—an increase in inflation should lead to upward pressure in interest rates, a decline in inflation should lead to a downward pressure in interest rates.

5) $STL = \Sigma (\beta_x I_t)$

¹³ The price index used is PCE chain-type price index less food and energy (PCEPILFE) and available on the St. Louis Federal Reserve FRED database at <http://research.stlouisfed.org/fred2/series/PCEPILFE>

STL is the St. Louis Federal Reserve Financial Stress Index, where I_t are the observed 18 economic indicators included in the index and β_x is the predetermined parameter coefficients of each of the 18 economic indicators. STL was included because I wanted to include an indicator of market expectations, but was unable to include University of Michigan Consumer Sentiment or Inflation Expectations to replicate the Gagnon model due to collinearity issues. With the St. Louis Financial Stress Index, it included a long enough period to include in the model while not tracking with inflation that caused statistically insignificant results. The sign of STL is expected to be positive, with a decline in interest rates typically leading to less stress on the financial market.

Regression Analysis

Table 1:
Descriptive Statistics Table:

	β_0	OMO	QE	FFR	URGAP	INFL	STL
Std. Dev.	n/a	1.6843	1.6786	2.120	1.6823	0.3927	1.056
Minimum	n/a	-11.74	-0.3093	0.11	-1.4	0.774	-1.165
Maximum	n/a	5.507	9.296	6.54	4.9	2.641	4.861
Mean	n/a	0.2449	0.530	3.321	0.41	1.847	0.096

Table 2:
OLS Regression on Various Long-Term Rates, July 1996-December 2010

	30 Yr. Mortgage	15 Yr. Mortgage	10 Yr. Treasury	5 Yr. Treasury	2 Yr. Treasury
Intercept (std. error)	6.307*** (0.260)	5.518*** (0.251)	4.419*** (0.292)	3.246*** (0.301)	1.468*** (0.260)

OMO (std. error)	0.0475** (0.024)	0.0501** (0.023)	0.0680*** (0.027)	0.0902*** (0.028)	0.0879*** (0.024)
QE (std. error)	-0.0736** (0.035)	-0.0580** (0.034)	-0.0621 (0.039)	-0.0245 (0.041)	-0.0112 (0.035)
FFR (std. error)	0.309** (0.035)	0.362*** (0.034)	0.334*** (0.039)	0.499*** (0.040)	0.751*** (0.035)
URGAP (std. error)	-0.173*** (0.051)	-0.173*** (0.049)	-0.049 (0.057)	-0.110* (0.059)	-0.099** (0.051)
INFL (std. error)	-0.431*** (0.109)	-0.357*** (0.105)	-0.417*** (0.122)	-0.345*** (0.126)	-0.153 (0.109)
STL (std. error)	0.167*** (0.048)	0.221*** (0.046)	-0.105** (0.054)	0.145*** (0.055)	-0.140*** (0.048)

***, **, * indicates significance at 1%, 5% and 10% levels respectively.

Table 3:
Summary Statistics Table:

	30 Yr. Mortgage	15 Yr. Mortgage	10 Yr. Treasury	5 Yr. Treasury	2 Yr. Treasury
Mean	6.45287	5.99206	4.71235	4.2154	3.65316
Std. Dev.	0.983	1.038	1.039	1.424	1.866
Root MSE	0.49668	0.47954	0.55875	0.57471	0.49786
Adj. R²	0.7447	0.7867	0.7108	0.8372	0.9288
D-W	0.241	0.306	0.250	0.275	0.294

Based on the anticipated plan of the large scale asset purchases, the purchases would be expected to have some sort of downward pressure on long-term rates. However, since the data series includes the entire period of the \$1.25T mortgage-backed securities and \$170B agency debt program that ran through March 2010, it would be most likely to see the change from the purchases in the mortgage rates. The expected sign exists for both the 30-year and 15-year mortgage rates, as a massive purchase of mortgage-backed securities would remove those from the market, driving the price of such securities up and lowering yields on the mortgage-backed

securities. The variable is statistically significant at the 5% level for 30-year mortgage rates and at the 10% level for 15-year mortgages.

Where quantitative easing becomes questionable in its direct effect is on other security rates such as Treasury bills. On the 10-year Treasury bill, the quantitative easing variable is statistically insignificant at the 1% and 5% levels and its t-statistic is right on the borderline for the 10% level, however because it's so close it is best to regard it as statistically insignificant. It maintains the expected sign of the effect of the large scale purchases, but since the targeted sector was not on Treasury bonds, but the housing sector, the true effect may be captured in other variables, such as economics factors (unemployment and inflation) or market expectations and uncertainty (St. Louis Stress Index). This is more specifically seen in the 5-year and 2-year Treasury bills where the quantitative easing variable is clearly statistically insignificant.

Quantitative easing has a negative impact on all five interest rates measured, but is only statistically significant for the 30-year mortgage at the 5% level and the 15-year mortgage at the 10% level. There are two likely reasons for the insignificant effect on Treasury bond rate. First, most of the purchases made by the Fed were specific to the mortgage sector, so the impact on Treasury rates would be lagged, indirect, or with a smaller magnitude. Secondly, the Treasury rates have a shorter maturity than mortgage rates, and as the models indicate, the coefficient of the QE variable becomes smaller as time to maturity decreases. This is consistent with the plan of quantitative easing, which was to lower long-term rates with the large asset purchases since short term rates were already low. While it is true that the second round of quantitative easing is focused on purchasing \$600 billion in Treasury securities in addition to their current purchase schedule to swap out maturing mortgage-backed securities with Treasury securities, only two months of the program are reflected in the time series used. Therefore, if this model is replicated

when the program is completed, it would be conditionally presumed that the quantitative easing variable may have a statistically significant impact on lowering T-bill rates. This can be revisited, which I plan to do upon the completion of QE2 to see if the model in fact does withstand the full purchases of both programs and maintain some sort of statistical significance.

Another intriguing development in the model was that open market operations had an unexpected sign: it was positive instead of negative. This is especially intriguing since OMO was statistically significant in each of the five equations. One potential cause of this could be double counting or miscounting of the open market operation variable. The \$300 billion in U.S. Treasury securities from QE1 was included in the open market operations variable and the H4.1 balance sheet was used by taking the number of securities held on the last release of each month. Since the last Wednesday of the month varies, there may have been inexact numbers on the balance sheet that were not indicative of what the Fed actually held on the last day of each month. Also, inflation did not maintain the expected sign. This could be due to the fact that core inflation does not have much variation over the period chosen, so the variation in core may not have been truly indicative of the actual changes in inflation of all goods. The oil shocks of 2008 were not adequately captured since food and energy are not calculated in core. In the future, non-core inflation would probably be a better option for this specific model—core was used for this calculation since it was used in the Gagnon model. Additionally, since the Fed Funds rate is included as an explanatory variable, the negative sign on inflation may result from longer rates responding less to changes in inflation than the Fed Funds rate.

The Fed Funds rate had a consistently positive sign as expected and was statistically significant for both mortgage rates and Treasury rates. However, if we look closely at the Fed Funds coefficients, their size increased as the time of maturity declined. This is consistent with

the theory of the term structure of interest rates—the shorter the maturity, the greater the magnitude of an effect the Fed Funds rate has. The unemployment gap's sign was negative and statistically significant for all of the rates measured except for the 10-year Treasury. The St. Louis Financial Stress Index maintained a statistically significant positive sign for mortgage rates and a statistically significant negative sign on Treasury rates. This is consistent with the investors' flight to safety with Treasury bonds in times of elevated financial stress.

The next thing to discuss is the magnitude of the change captured by the model. For the 30-year mortgage rate, there is a 7.36 basis point drop in the rate for a quantitative easing purchased that is equivalent to 1% of the monetary base. So for a 1% increase in the monetary base due to large scale asset purchases, there is a 7.36 basis drop. Using the monetary base from December 2010, according to the results, it would take a \$20 billion purchase to lower the 30-year mortgage rate by 7 basis points. For the 15-year mortgage rate, there is 5.80 basis point decline due to quantitative easing for a purchase equivalent to 1% of the monetary base. For the 10-year Treasury bill, there is 6.21 basis point decline for a purchase equivalent to the 1% of the monetary base as a result of quantitative easing. However, due to statistical insignificance we cannot identify the reliability of the magnitude of the asset purchases directly on this or the 5-year and 2-year Treasury bill rates. Though the results are significant for the mortgage rates on the QE variable, it is necessary to recognize that there is serious positive serial correlation associated with the model. This can possibly attributed to the model being mostly in level form or various macroeconomic variables in the model (Fed Funds, unemployment, inflation, market expectations) having impacts on each other.

Conclusions

The main conclusions we can find from this regression model is that quantitative easing through December 2010 did have a significant negative effect on the mortgage rates, which can be attributed to the Fed's purchase of mortgage-backed securities. As QE2 approaches its completion, we may see that quantitative easing as a whole may have a direct effect on all of the interest rates measured. However, until the second round of large scale asset purchases is fully completed, the results of medium-ranged Treasury securities and even the 10-year Treasury bill remain inconclusive. The model will be revisited in the summer to see if in fact the model can capture a significant marginal partial effect that the asset purchases had on the rates and not an indirect cascade that can be attributed to a wide variety of economic factors changing due to the purchases or due to expectations by the markets. The difficulty of choosing a model that captures a snapshot of dynamic variables almost all endogenous of each other also shows the difficulty that the policymakers and the Federal Open Market Committee have when trying to determine and optimal policy to enact. To compare this model to the San Francisco Fed's historical predictions, according to the 10-year T-bill regression function, a 2 percentage point drop in the Fed Funds rate would lead to a 66 basis point decline in the rate, compared to 50 basis point measured in Chung. The entire purchase program of QE1 would lead to an 80 basis point drop in the rate, which shows more effectiveness than the district bank's analysis, but can also be questioned due to its lack of statistical significance.

Future Research

One way to compare this data would be to compare effects to the quantitative easing policies enacted by the Bank of Japan in the 2000's. However, in order to do this comparison

much more simplified variables would have to be used since the economic indicators used in Gagnon, Raskin, Remache and Sack (2010) and this model are specific to the U.S. economy, and the fact Japan's short term target rates have not changed in over a decade. Furthermore, a comparison may be difficult since Japan was mainly attempting to counter deflation while the United States was concerned not only about relatively low inflation, but curtailing abnormally high unemployment rates and promoting economic activity and lending.

Another thing that could be considered during future analysis is to determine whether the rate of the securities purchases had an effect on the effectiveness of quantitative easing. In a 2010 speech by Brian Sack¹⁴, he mentioned that there were months where the effectiveness of quantitative easing was compromised by the Fed purchasing too high of a proportion of the available securities on the market. While this is the goal, since cutting off the market would lead to prices going up, and in turn lowering the yields on longer-term assets, if there are none to purchase and sell, then it hurts the market's flexibility. It is difficult to estimate the effects of rates with the volatility in the market over such short time series—with only two years of data in the domestic economy with this policy implemented. This is something that should be mentioned but is not feasible to be deeply analyzed at this time due to limited data. However, it could be something that can be further researched once QE2 is completed, more central banks engage in similar programs and quantitative easing's role is further expanded in U.S. monetary policy in the future in a capacity similar to Japan's.

One last thing that could be implemented into later research is analyzing the effect of the Fed's transparency in recent years about the asset purchase programs and their effect on long-term rates. Using dummy variables to acknowledge when the announcements were and were not

¹⁴ Sack's October 4, 2010 speech "Managing the Federal Reserve's Balance Sheet can be found at: <http://www.newyorkfed.org/newsevents/speeches/2010/sac101004.html>

made for QE1 and QE2, especially prior to the actual commencing of the purchases, we could possibly see how beneficial the open discussions by the FOMC were on the overall efficacy of the programs. When running other variations of our model, we incorporated a QE1 and QE2 dummy variable. The results showed a significant impact of the transparency of the Fed on QE2 and drops of long-term rates to their historically low levels, while QE1's announcements were statistically insignificant. However, due to the level forms of the model and high Pearson correlation coefficients between the dummy variables and the QE variable, we omitted this from our final model.

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