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The Impact of Unanticipated Inflation on Long-Term Treasury Bills

An event study on the U.S. market

by

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Abstract

The impact of inflation on Treasury bills has not been studied for many years and hence the effects in modern time are unclear. The long term interest rates are theoretically more difficult to influence as future expectations needs to be changed. This study hence aims to mainly examine the effects of unanticipated inflation on the U.S. treasury bills but also the effects which unanticipated money supply has as a complementary part. An event study methodology has been used to conduct the research, which is the standard in previous studies. The results show that the unanticipated inflation announcements in the form of PPI have a significant positive impact on the sample from 1990-2015 whilst CPI has no impact. The reason for this is assumed to be the early announcements of PPI compared to CPI. When examining the results Pre and Post the global financial crisis a clear difference can be seen. The large difference is assumed to exist because of the strong and persistent regulatory interventions form the government. The Results also show that money supply has no impact on the long-term treasury bills in this sample.

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1.0 INTRODUCTION

Most Central Banks have an inflation targeting policy, which shows the weight and importance that we put on inflation. Inflation targeting means that we give up the freedom of a free floating interest rate in order to control the inflation. In recent years we have seen how the dynamics of the world economy has been tumbled around. We have experienced large events, which has affected the economy significantly. Events such as the financial crisis of 2008 and the fall of Lehman Brothers, but also the recent extreme drop in oil prices. These extreme macroeconomic events put a large constraint on output and therefore also on the inflation.

Central banks use the interest rate as an effective tool to regulate the inflation level. Most central banks intervene and temper with the interest rate to create or put a stop to spending in order to control the inflation which is caused by extreme events and situations. These strong and continuous interventions are not natural and could hence affect the impact which inflation has on interest rates. Therefore the market's reaction to inflation might differ after the financial crisis compared to before.

The inflation that the market expects is not always equal to the real inflation rate and when this happens the bond markets are in disparity since the nominal rates follow the market's inflation expectation. So the question that ascends is how and to what extent the interest rates are affected by a surprise in the inflation rate. According to theory, this depends mainly on how the unanticipated (surprise) information changes the market's expectation of inflation. A temporary alteration in our expectation should only affect the short-term interest rates, whilst a permanent alteration is needed in order to affect the long-term interest rates.

Not many studies have been conducted on this topic in recent decades, there have however been a few in the past. That includes research such as the one conducted by Urich & Wachtel (1984), where they concluded that both unanticipated PPI and money supply have a positive impact on the Three-month Treasury bills. Additional contribution to the literature have been made by Smirlock (1986), whom conclude that the 10-, 20- and 30-year Treasury bills react positively to unanticipated CPI, PPI and money supply.

This study will attempt to examine if the results from the past still remain in a modern time frame with more macroeconomic volatility. Not all information is strong enough to change our expectations permanently (long-term), hence the impact on the long-term rates are less uncommon and more interesting to research. In addition, a change in the interest rate of a security with long time horizon affects the price of that security to a greater extent than a security with short time horizon. This is true because the security with a longer horizon exhibits a larger compounding effect. Therefore the study of long-term rates becomes more fascinating.

1.1 PURPOSE

This study aims to examine the impact of inflation and more specifically the impact of unanticipated inflation on the long-term federal interest rates (Treasury bills) in the U.S. economy during the past 25 years. This is important in order to understand and recognise the effects which inflation has on the safest assets in the economy. The inflation is difficult to quantify and will hence be measured and regressed both directly through Consumer Price Indexes (from here on referred to as CPI) and Producer Price Indexes (from here on referred to as PPI) but also through the money supply. The paper will also try to distinguish if recent time's macroeconomic turmoil has led to a different reaction in the interest rates by examining the results pre- and post- the Global Financial Crisis (from here on referred to as the GFC). Based on the introduction and the purpose of the study the main research question will be:

"*Does the unanticipated inflation impact the long-term Treasury bill rates in the U.S.*?"

1.2 EXPECTED CONTRIBUTION

Since studies in this area are scarce and out-dated, the contributions are expected to inform and update markets on the impact which unanticipated inflation has on recent market conditions. The study is also expected to provide evidence on the relative importance of the different information sources of inflation in the eyes of the market.

2.0 THEORY

In this section of the paper we will go through the relevant theories in connection to the research, the theories are related to how the money supply and inflation affect the interest rate but also on the efficiency of the market.

2.1 FISHER HYPOTHESIS

The fisher equation from 1930 is a fundamental link between interest rates and inflation, which is used to understand how real and nominal rates are connected.

$$i_t = E_t(r_{t+1}|I_t) + E_t(\pi_{t+1}|I_t) \quad (1)$$

The Fisher equation tells us that the nominal interest rate (i) is equal to the real interest rate (r) plus the expected inflation (π). The real interest rate is often seen as constant, which is reasonable as most countries have inflation targeting meaning that the central bank sets the interest rate to control the inflation. Thus the change in the nominal interest rates must come from the change in expected inflation. The above equation tells us that the expectations of the variables are dependent on the information available at time t and thus real interest rates are affected through a change in the information set. Hence the announcements, which we will examine, change the expectations by adding information. (Cooper & John, 2011, pp. 125,134)

It's important to understand that the announcements will never affect either the real money supply or real inflation, they will only affect our expectations of them. To further explain the reactions and interpretations of both unexpected inflation and monetary supply we will below explore some of the channels through which these announcements can affect the asset-prices (rates). (Cornell, 1983)

2.1.1 EXPECTED INFLATION HYPOTHESIS

The clearest and probably the most important channel which inflation can take to affect the interest rates is explained through the expected inflation hypothesis. The theory explains what would happen to asset-prices if the announced inflation (real inflation) deviates from the expected inflation.

$$Unanicipated\ Inflation = Real\ Inflation - Expected\ Inflation$$

According to the theory a positive unanticipated inflation would mean that market participants would need to revise their expectations of the inflation upwards. Since the expected inflation is a stochastic part of the nominal interest rate, according to the fisher equation, this would lead to the nominal interest rate also being revised upwards. The alteration only happens if the anticipations of the inflation are affected. In the short-run this might be reasonable to assume, however in the long-run it is not as clear-cut. For the long-run interest rates to be affected the realized unexpected inflation needs to alter our anticipations of future expected inflation, hence the participants most have a permanent alteration of their expected inflation. If this is the case the short-term and long-term interest rates should change. If this is not the case then the long-term interest rate would probably remain unaffected or have a small insignificant change. (Cornell, 1983)

The money supply can also have an effect on the expected inflation. If we exhibit an unanticipated increase in the money supply it would make us alter our expectations of future inflation upwards. However this impact is expected to occur several months after the announcement, and since this study is examining the immediate effect, this part of the theory is irrelevant. (Urich & Wachtel, 1984)

2.1.2 POLICY ANTICIPATION HYPOTHESIS

A second channel for which the interest-rates can be affected is through the money supply. It works in very much the same way as the expected inflation hypothesis. If market participants recognize an unanticipated change in the money supply, it will lead them to believe that the Central Bank will attempt to control and hence compensate for this change. An unanticipated increase in the money supply would lead to a rise in the interest-rate since the market would anticipate the Central Bank to tighten the supply of reserves through open market operations. This expectation would lead the market to drive up the interest rates by bidding on the funds. Given that the anticipated monetary restraint is expected to be short-lived the effects will according to the policy anticipation hypothesis not be shown in the long-term interest rates, an impact will however be reflected in the short-term interest rates because of the liquidity effect.

On the other hand, if the market expects the monetary restraint to last for a longer period this will also be revealed in the long-term interest rate. (Cornell, 1983; Urich & Wachtel, 1981)

2.1.3 REAL ACTIVITY HYPOTHESIS

The real activity hypothesis describes the link between money supply announcements and interest rates. This link is based on the principle that the announcements contain information about future money demand. Fama (1982) argues that this principle holds because current money demand depends on expected future output. Since the individual investor only can see his/her own individual money demand and not the aggregate money demand, they need a source of information for the aggregate demand. The money supply announcements reveal information about expected future output and hence also about the money demand. For example if a money supply announcement shows an unexpected increase, this would imply that the aggregate money demand is much higher than what they previously believed or forecasted. The expected future real activities (output) will rise based on the information conveyed from the announcements. The increase in expected future output leads to a rise in real interest rates for the purpose of clearing the market for consumption and investment. The reaction in the long-term interest rates is ones again a bit different, depending on the expected magnitude of the announcement. (Cornell, 1983)

The long-term rates will be affected only if the market participants believe that the announcement will have a permanent effect on output over the life-time of the bond. If the announcement only affects the expected output temporary, then the long-term interest rates will probably not be affected to the same degree as the short-term interest rates (if any). (Cornell, 1983)

2.2 THE EFFICIENT MARKET HYPOTHESIS

The Efficient Market Hypothesis (EMH) first developed by Eugene Fama (1970) suggests that security prices at any time fully reflect and incorporate all available information on the market. The EMH can be divided into three sub-categories; strong-, semi-strong- and weak-form of market efficiency. A strong-form of market efficiency would be represented by security prices that reflect all available information, even the information that only is known by a specific group of people. This strong assumption is however considered to be non-realistic.

The Semi-strong-form of efficient market hypothesis relax these strong assumptions and considers whether the security prices reflect all information that is available for the public but does not include any sort of insider information.

The last form of market efficiency is the so called weak-form of market efficiency which relaxes the information assumptions even further, here Fama (1970) considers a market to be weakly efficient if the prices of the securities incorporate information about historical prices. (Fama, 1970)

The EMH suggests that the interest rates already incorporates the expected rate of return of the bonds and also the expected inflation in the price of the Treasury bill, and that it is the unanticipated inflation that will affect the bond yields after the publication of the actual inflation rate. In the article by Fama (1975) the results support the hypothesis of an efficient bond market for one- to six- month treasury-bills.

3.0 PREVIOUS RESEARCH

Previous researchers have examined the impact of macroeconomic news on the return of the stock and bond markets. The previous studies have however mostly focused on the short-term bond yields and are not to a great extent studied for long-term bonds. Also most studies in this topic are our-dated. In this section we will go through relevant studies regarding the impact of inflation announcements and money supply on Treasury bonds.

Urich & Wachtel (1981) studied how the interest rate reacts to weekly announcements about the money supply in the US. The study is based on data from the period 1970 to 1979, where the daily change in the three-month T-bills is used as the dependent variable. For money supply the authors use the seasonally adjusted weekly announcements of money supply, M1. And the expected money supply is based on two different measures: one is based on market expectations derived from a survey conducted by The Money Market Services, the company did however start with their survey in 1977 hence it could not be used for the entire sample. The second approach of measuring the expected money supply is based on an ARIMA model. Results of the study show that the two different ways of measuring expectations generally generate similar results. The basic empirical model that is tested regress the anticipated money supply and the unanticipated money supply on the change in interest rate. Given the EMH, only the unanticipated change in money supply should have a coefficient different from zero. The conclusions the authors make based on the result from the study is that it is only the unanticipated change in money supply that has a consistent effect on the interest rate. Further, the reaction in the interest rate seemed to be realized immediately after the announcement. The degree of response in the interest rate to these changes has however varied quite a bit in the period that is studied. They also conclude that the announcement effect supports the policy anticipation hypothesis.

Roley (1983) examines how the short-term interest rate reacts to weekly announcements about the money supply. The sample period used in the study is from September 1977 until October 1982. The sample is divided into sub-periods with breaks around the change in policy regime, the 6th of October 1979, and again when the money definition changes in the end of January 1980. Roley (1983) uses a similar model to the one previously used by Urich & Wachtel (1981) where they examined the announcement effect by using both expected and unanticipated changes in the money supply. Both studies use the same measure of expected

money supply, which is gathered from the survey conducted by the Money Market Services. Roley (1983) do however extend the basic model used in previous research by for example allowing a nonlinear response in the short-term interest rate to unanticipated money supply. The model was also extended through allowing the response in the short-term bond yield to differ depending on the connection between actual money stock and the FEDs long-term targets. The results of the different samples show that the three-month Treasury bill's reaction to unanticipated changes in money supply is statistically significant. They also conclude that the reaction or response in the yield of the Treasury bill has increased since the policy regime change in October 1979. Further, the result of the study indicates that there has been an increased volatility in the unexpected money supply, which has contributed to a higher volatility in the interest rate.

In a second study by Urich & Wachtel (1984), the authors examine how the changes in inflation and money supply impact the interest rates. The data used in the study has a sample period from November 1977 to July 1982 and is studied on the U.S. market. The dependent variable used is the daily change in the interest rate, where the interest rate is based on future contracts on three-month to 1-year Treasury bills. For the variables that are representing the change in inflation, the change in CPI and the change in PPI are used, both of which are seasonally adjusted. The changes in the inflation variables are measured as a percentage change from previous months announcement where these announcements are published on a monthly basis. Another variable that is used is the change in M1 money supply, which is defined as the weekly change in billion dollars of the money supply. The authors in the study use an event- methodology in which they regress the anticipated inflation change and the unanticipated inflation change on the change in interest rate. The time period studied is divided into two sub-periods due to the structural change for the FED in October 1979. The result of the study shows that the unanticipated change in PPI has a direct positive effect on the short-term interest rate, while the study does not prove a statistically significant reaction to the unanticipated change in CPI. This result is explained by the fact that the PPI announcements are disclosed a few days prior to the CPI. Further the study shows that the policy anticipation effect through the change in money supply is greater after the operating-shift in procedures by the FED, which is consistent to the result in the study by Roley (1983).
The empirical analysis shows evidence of immediate incorporation of the announcements and there is no evidence of a delay in the markets response to the announcments. (Urich & Wachtel, 1984)

The study by Smirlock (1986) investigates the impact of inflation announcements on long-term bonds based on data from January 1979 to December 1983 in the U.S. market. The author uses an event-time methodology where the dependent variable is measured as the change in the long-term interest rates (10-, 20- and 30-year Treasury bills). As independent variables both the anticipated and the unanticipated inflation is used. The inflation announcements in this study are monthly publications of the CPI and the PPI, whilst the unanticipated inflation is measured as the difference between the expected inflation and the actual inflation. The expected inflation is a measure that is gathered by the Money Market Services, which conduct services before announcements in order to determine the markets expectations. The median of the expectations sample is used in the study. The result of the study shows that the market does not respond to the anticipated inflation announcements, only to the unanticipated inflation. This result is also consistent with the efficient market hypothesis. The response of the unanticipated CPI and PPI changes is seen to have a direct effect on the long-term bond yield, however this is only the case in the post-1979 case and in the pre-1979 case no effects are statistically significant. This result is somewhat different from the study by Urich & Wachtel (1984) since they did not find that the unanticipated CPI announcements had a statistically significant impact on the interest rate. The findings of the research furthermore conclude that the response in the interest rates based on the unanticipated inflation announcements is adjusted by the end of the announcement day.

The table below summarizes previous research in this field of study. From the table it can be seen that this kind of study has not been conducted on the U.S market since the 1980's and hence the empirical literature is limited.

Author	Sample	Interest rates	Inflation	Money supply	Expected Inflation	Expected money supply	Method	Significant result
Urich & Wachtel (1981)	U.S. (1970 - 1979)	3-month T-bills		M1		Money Market Services & ARIMA-Model	Event study	M1 = Positive Impact
Roley (1983)	U.S. (1977 - 1982)	3-month T-bills		M1B & M1		Money Market Services	Event study	M1B & M1 = Positive Impact
Urich & Wachtel (1984)	U.S. (1977 - 1982)	3-month to 1-year T-bills	CPI & PPI	M1	Money Market Services	Money Market Services	Event study	PPI & M1 = Positive Impact
Smirlock (1986)	U.S. (1979 - 1983)	10- / 20- / 30-year T-bills	CPI & PPI	M1	Money Market Services	Money Market Services	Event study	CPI, PPI & M1 = Positive Impact
Huberman & Schwert (1985)	Israel (1970 - 1979)	5- 10-year Index bonds	CPI		Time series prediction model		Event study	CPI = Positive Impact
Tessaromatis (1990)	U.K. (1982 - 1986)	Indexes of all maturities		M3		U.K. Survey	Event study	M3 = Positive Impact

Note: M1, M1B and M3 are different measures of money supply.

Money Market Services use surveys to create a measure of expected inflation & expected money supply.

Blank spots in the table exist because some studies investigate the impact of only money supply whilst others study the effect of CPI and PPI.

Table 1. Quick summary of previous research

4.0 METHODOLOGY

This section describes the event study methodology and the empirical model used in this study. Finally the data used will be examined and the origin of the data will be presented.

4.1 EVENT STUDY

In order to examine how the long-term bond yield reacts to announcements of the inflation and the money supply an event study methodology will be used. An Event study is the best and easiest way to measure the effects of an economic event (MacKinlay, 1997), therefore the methodology is suitable for this study since the purpose is to observe the response in the interest rate to the different inflation and money supply announcements. The method is also the preferred one in previous similar studies as can be seen in table 1. Hence for the sake of comparability it makes sense to use this approach.

4.2 GENERAL EVENT STUDY METHODOLOGY

There is no precise step-by-step procedure for conducting an event study, the process depends heavily on the effects and type of event that is being measured. However there are some main principles, which all studies have in common, which we will go through below. (Peterson, 1989)

4.2.1 EVENT WINDOW

To be able to conduct an event study it is important to be able to identify and specify the event in question. Once the event is identified the event window needs to be determined. The event window should be the time period in which the impact is expected to take place. It is important to choose an even window that is greater than the event itself. (MacKinlay, 1997) In this study an event window of one day should be enough as the event is information release, which happens instantaneously. However the study will employ an event window of +1 day, in case of market inefficiency. The longer window will allow us to observe delayed effects from the events.

4.2.2 ABNORMAL RETURNS AND ESTIMATION

The effects that are seen from different events are materialized in the form of abnormal returns, meaning any return that is significantly more or less than the expected return on the security (Normal Return). The abnormal returns are simply the difference between the observed returns and the normal return

$$AR_{it} = R_{it} - R_{it}^{*} \quad (2)$$

In the above equation R_{it} is the observed return and R_{it}^{*} is the estimated normal return. The normal return can be estimated through different models depending on the study. For event studies in the equities market the market model is the preferred estimation model, and in the debt securities market usually the mean-adjusted model is used, however this will vary a lot from study to study. All these models require an estimation window before the event window that will be used to estimate the normal returns (MacKinlay, 1997).

This type of study is however somewhat different from the regular event study, as it does not predict the normal returns with a forecasting model. This study will examine the effects of money supply and inflation announcements in the same manner as the studies conducted by Roley (1983), Urich & Wachtel (1981, 1984) and Smirlock (1986). The reason for not being able to use a traditional forecasting model as the ones explained above is because this study and all the previous studies mentioned are examining the effects on T-bills. With other words they are examining the effects on the risk-free rate, which is a part of all the forecasting models. Below we will go through the basic models for examining and hence predicting the change in T-bills.

4.3 BASIC MODELS IN T-BILLS

From the theory chapter it can clearly be seen that the surprises in the announcements can take different channels in affecting the interest-rates (Cornell, 1983). Hence this study will in the same way as Smirlock (1986) use two different models to account for these affects through different channels, one model for the inflation announcements and another one for the money supply announcements.

The models will use the daily change in the U.S. 5-, 10-, 20- and 30-year Treasury-bills as the dependent variables, which we regress against the inflation and money supply. Each independent variable will have its own model and these will be explained below. (Smirlock, 1986)

4.3.1 INFLATION MODEL

The Inflation model is a direct result of the Expected Inflation hypothesis which was explained in the theory chapter above. The hypothesis explained how asset-prices would react to anticipated and unanticipated inflation which is tested through the following model (Cornell, 1983)

$$\Delta R_{it} = \alpha_0 + \alpha_1 A_t + \alpha_2 U_t + \varepsilon_t \quad (3)$$

The model is attempting to explain the change in interest rates with inflation announcements which is the sole largest influence on the interest rates according to the fisher equation (Cooper & John, 2011, pp. 125,134). Here ΔR_{it} is the percentage change in the security price from the day before calculated in the following way:

$$\Delta R_{it} = ln\left(\frac{P_{it}}{P_{it-1}}\right) \quad (4)$$

Where P is the price of the security. A_t is the anticipated inflation which is what people expect the inflation announcement to be. U_t is the unanticipated inflation which is the difference between the actual inflation retrieved from the inflation announcement and the anticipated inflation as shown below:

$$U_t = Actual\ Inflation - Anticipated\ Inflation \quad (5)$$

α_0, α_1 and α_2 in equation 3 are the intercept and coefficients which measure the impact of each independent variable on the interest rate change.

Since A_t is the anticipated (expected) inflation, it should already be incorporated into the asset-price in an efficient market. Hence we expect α_1 to be equal to zero. If we observe the α_1 coefficient to be significantly different from zero we can suspect an inefficient market.

For this reason A_t could be seen as an irrelevant variable which only exists to check for the market efficiency and accuracy of the model.

Since U_t examines the unanticipated inflation, it is expected that α_2 will be significantly different from zero if any unanticipated inflation would change the future expectations of inflation as according to the expected inflation hypothesis (Smirlock, 1986; Cornell, 1983).

4.3.2 MONEY SUPPLY MODEL

The interest rate can be affected from other channels than the inflation announcements as was described in the theory section. One of the more influential channels is believed to be the money supply which according to theory could affect expectations in several different ways (Cornell, 1983; Urich & Wachtel, 1981). The following model will help examine the effects of the money supply announcements on the interest rates:

$$\Delta R_{it} = a_0 + a_1 \Delta M_t^e + a_2 \Delta M_t^u + \varepsilon_t \quad (6)$$

This model is very similar to the inflation model exhibited above. ΔR_{it} is the change in interest rates and is estimated through equation (4). ΔM_t^e is the markets expectation of the announced money stock. ΔM_t^u is the unanticipated money stock, which is the difference between the announced and the markets expected money stock as shown below:

$$\Delta M_t^u = \Delta M_t - \Delta M_t^e \quad (7)$$

Where ΔM_t is the actual announced money stock at time t.
The intercept and estimated coefficients a_0, a_1 and a_2 from equation (7) are interpreted in the same manner as the ones in the inflation model. Once again a_1 is expected to be equal to zero in an efficient market as any anticipated change in the money supply should already be incorporated in the asset-price. (Roley, 1983)

a_2 is expected to be significantly different from zero if any unanticipated change in the money supply would contribute with information that alters market participants future expectations according to the policy anticipation hypothesis and real activity hypotheses (Cornell, 1983; Urich & Wachtel, 1981).

4.4 DATA

The empirical tests conducted in this study are based on daily prices of US Treasury bills, the monthly announcements of CPI and PPI, and the weekly announcements of the money supply. The data used in the empirical tests are gathered from DataStream and from the federal reserve bank of St. Louis.

4.4.1 SAMPLE PERIODS

The period of study regarding the regressions with CPI and PPI in this paper is from 1990-01-01 until 2015-03-30, the exact starting date do however vary to some degree based on the relevant first announcement of the year. The starting date for the regressions where the 20-year Treasury bills are used as the dependent variable is also somewhat different because of the fact that the data is not available until late 1993. When it comes to the regressions with money supply as independent variables the exact dates of the announcements were only available from 1999 and forwards, hence the sample where the regressions uses money supply will start from 1999 instead. In order to get earlier dates one would need to make a Freedom of Information request which would then be processed and hopefully accepted by the Federal Reserve's board (Federalreserve, 2015).

Apart from testing the entire sample, the study also examines the effects of the unanticipated inflation and money supply on the long-term interest rates before and after the GFC. The break is created based on the reasoning that during this period the market does not react naturally to new information (Lam et al., 2011). Since 2008 there has been a large inflow of money through quantitative easing (QE). Quantitative easing means that the central banks have bought large amounts of government bonds, this might affect how the interest rates react to the inflation and money supply announcements. For this reason there might be a different response in the interest rate pre and post the GFC.

There is no clear time interval for the beginning and the end of the GFC. Different studies have used different methods to decide the time interval of the crisis. Hoffman, Post and Pennings (2012) used a sample period between April 2008 and March 2009 as their interval for the financial crisis. They based these dates on the stock market reaction. In the beginning of the sample the stock market were relatively calm and in the end of the sample it had started to recover.

So in this interval the months that were hit the hardest, surrounding the Lehman Brothers collapse, were included. Further, Chen et al. (2012) defines the period of the GFC with the most severe effects on the market as 1st of august 2008 until 30th of December 2009. Other studies such as; Mahgyereh, Awartani & Hilu (2014) & Westerlund et al (2013) do not use a time interval to define the GFC to further examine the pre- post effects. Instead they break their sample at a specific date, which they then use to distinguish between pre- and post GFC. Mahgyereh et al (2014) break their sample at the end of August 2008, while Westerlund et al (2013) break their sample at the 12th of September 2008.

Based on previous reasoning the data in the sample during the GFC is removed and the tests are performed on the pre and post GFC sample. The GFC time interval is defined as the 1st of June 2008 until 31th of March 2009. The specific interval is selected based on previous studies and also the reaction on the US stock market indexes. The stock market indexes are relatively stable until the beginning of June, hence the sample before the 1st of June will in this study be defined as the pre GFC sample. Further, the Dow Jones Industry Average index showed during the crisis its lowest price on the 2nd of March 2009. Other indexes such as the NASDAQ and the S&P 500 index had their lowest price on the 9th of March 2009. Hence, to account for these dates the post crisis sample will start the 1st of April.

4.4.2 INTEREST RATE

In the research, four different U.S. Treasury bills are used as the interest rates. The four measures are the: 5-, 10-, 20- and 30-year Treasury bills, which reflect different classifications of a long-term interest rate. Each Treasury bill is used as the dependent variable in the study, were they are expressed as the continuous compounded return of the Treasury bill (see equation (4)). The interest rate data is collected from Datastream with the starting date of 1990-01-01 with an exception for the 20-year interest rate for which data was only available first 1993-10-01.

4.4.3 CONSUMER PRICE INDEX

The Consumer Price Index (CPI) is a measure of inflation that is announced each month. It measures the evolution of the price paid by urban consumers for a representative basket of goods and services (Bls.gov). The independent variables concerning the consumer price index in this study are divided into two parts: Anticipated CPI and Unanticipated CPI.

For the “Anticipated CPI” variable we use the proxy: Expected inflation, which is a measure of expected inflation gathered by The University of Michigan. The variable is a relative measure that is compared to the price level from the same period last year. The data is gathered from the Federal Reserve Bank of St. Louis. (stlouisfed.org, 2015)

The actual CPI is measured as the relative change compared to the same period last year which was also gathered from the Federal Reserve Bank of St. Louis. The variable “Unanticipated CPI*”* was then constructed by taking the difference between the actual and the anticipated CPI. (stlouisfed.org, 2015)

4.4.4 PRODUCER PRICE INDEX

Similarly to the CPI, the Producer Price Index (PPI) is also a measure of inflation. It measures the average price change that a producer receives for his/her goods (Bls.gov). The variables related to the PPI are in the same manner as in the CPI the “Anticipated PPI” and “Unanticipated PPI”.

For the variable “Anticipated PPI” the same proxy is used as for the Anticipated CPI, that is, the expected inflation measure gathered by the University of Michigan, hence they are identical. (stlouisfed.org, 2015).

The “Unanticipated PPI” is constructed in the same manner as the Unanticipated CPI, by taking the difference between the actual PPI and the anticipated PPI. (stlouisfed.org, 2015)

4.4.5 MONEY SUPPLY

The “Money supply model” (which can be found in equation (6)) is made of three variables, Interest rate, Anticipated Money Supply and Unanticipated Money Supply, where the later is constructed through taking the actual money supply and subtract the anticipated money supply. The Actual Money Supply was gathered from Datastream and is the seasonally adjusted M1. This is a liquid measure of money supply that contains the amount of currency plus checkable deposits. The main reason why M1 is used in the study is because most of the previous research has used this measure, hence making it possible to compare the result of this study with previous findings. (federalreserve.gov, 2015)

Previous relevant research on the U.S. market has to a large extent used a market survey of the expected money supply conducted by Money Market Services Inc. (Smirlock, 1986; Urich & Wachtel, 1981; Roley, 1983). The data from the survey is however not available for the public and could therefore not be used in this study. As an alternative approach to the surveyed estimates of the anticipated money supply an ARMA model will be used to make forecasts of the weekly money supply. The method of using an ARIMA model as a proxy for the unanticipated money supply has previously been used by Urich & Wachtel (1981). They concluded that the survey from Money Market Services and the ARIMA model yield similar results. Hence, we believe this to be a good proxy for the anticipated money supply.

The autoregressive moving average model, ARMA, is composed of autoregressive, AR(p), and moving average, MA(q), components. This means that the ARMA model of a variable, Y, is a linear combination of previous values of the variable itself, and of past and present values of the error term (Brooks, 2008).

This study aims to use the ARMA model in sole purpose of forecasting the money supply in order to use as a proxy for the anticipated money supply, which thereafter will be used in the event study. Hence, the residuals will not be used in further time series regression. For this reason it is not relevant if the data is stationary as Brooks (2008) states. Consequently we disregard the fact that the correlogram showed signs that the money supply data was non-stationary and that the null hypothesis of a unit root could not be rejected for the ADF and the PP test[1]. In this case one would usually take the first difference in order to obtain stationary data to prevent unwanted influence on the forecasts behaviour and properties (Brooks, 2008). The authors of this study have however for the reasons mentioned above decided to proceed with the original time series data without adjusting for its non-stationary properties.

To identify the most suitable order of the ARMA(p,q) model the Box-Jenkins approach has been used, which is based upon three different steps: (1) Identification, (2) Estimation and (3) Diagnostic checking. (Brooks, 2008)

[1] Unit root test with Augmented Dickey-Fuller and PP have been performed with a: constant, constant and intercept, constant, intercept and drift term. Consistent for all tests is that the null hypothesis cannot be rejected. KPSS test was also performed to test the opposite hypothesis, i.e. that the data is stationary, and this hypothesis was rejected on a 1 % significance level.

According to the correlogram in appendix B one can clearly see a decaying acf, and a pcf that is significant on the first lag, which suggests that an AR(1) model should be used. However, the correlogram is not always the best method to identify the order of the ARMA model. Therefore, an information criteria approach was also conducted in order to get a more accurate model. The three measures of the IC differ in the way they are specified and how much they punish an extra term and this could lead to different results in form of the optimal model. When trying the different ARMA(p,q) models up to ARMA(6,6) in search for the lowest value of the IC measures we could see that AIC and HQIC yields the same best model ARMA(4,5), the SBIC on the other hand proposes that the ARMA(1,2) is the better model. The AIC measure is known to get a model with too many lagged terms, it is argued that it does not "punish" the additional terms enough, and therefore it is believed that the SBIC generate a more true and unbiased measure. Based on this reasoning the use of the ARMA(1,2) model appears to be best suited for this study. (Brooks, 2008)

After determining the ARMA(p,q) model an over-fitting test was conducted, which is a model checking method to make sure that the right model has been selected. These results indicated that the same model should be used, i.e. the ARMA(1,2) model. The result showed that there were no insignificant terms in the ARMA(1,2) model and any additional terms in a higher order model were insignificant. (Brooks, 2008)

In order for the ARMA model to be used to forecast the weekly money supply a static forecasting model with a one-step-ahead (one-week-ahead) forecast was conducted, the result of the forecast and its accuracy is shown in appendix B.
Finally, the variable "Unanticipated Money Supply" was constructed by taking the actual money supply (M1) and subtracting the anticipated money supply that was obtained by forecasting the ARMA(1,2) model.

4.5 PRACTICAL IMPLEMENTATION

When extracting and downloading the monthly data regarding the CPI and the PPI announcements it was displayed on the 15th of each month even though this was not the correct date of the announcements. Since the exact dates of the new information are key in the event study the accurate dates of the announcements were gathered from the Bureau of Labor Statistics.

Next, Excel was used to match the effects of the announcements with the correct dates. Similarly when collecting the data for the announcements of M1 it was displayed on Wednesdays. The M1 is however generally released on Thursdays, given that it is not a federal holiday. Therefore the correct dates of the M1 announcements were extracted from the Federal Reserve and later matched with the data from the announcements. The variables were then converted into the measures that later were going to be used in the regressions, these measures were explained in detail in section 4.3.

After sorting and converting the sample of variables in Excel, the ordinary least square (OLS) method was used to conduct the relevant regressions. With the following hypothesises:

H_0: The events have no impact

H_a: The events may have impact

The models were estimated using the statistical program Eviews. After performing the regular OLS regression the models were also tested for serial correlation using a Breusch-Godfrey LM test and for heteroskedasticity by conducting a White test. Given that a model showed signs of only heteroskedasticity the model was then adjusted by using White heteroskedasticity-consistent standard errors and covariance. If the model indicated that both serial correlation and heteroskedasticity were present in the residuals, this was corrected for by instead using HAC standard errors and covariance. (Brooks, 2008)

4.6 METHODOLOGICAL ISSUES

When employing an event study methodology in a study, issues may arise which could affect the results of the study. There is no standardized way of conducting an event study, since all studies are different and could face different issues. Here some of the issues that might be relevant in this event study will be identified. (Peterson, 1989)

4.6.1 TIME PARAMETERS

One possible issue with the study could be that the daily closing prices, instead of intraday data, of the bonds are used to create the dependent variable. Ozdagli (2013) suggests that an event window of between 30 to 60 minutes would be enough to measure the effect of the macroeconomic release on the asset price,

while its also small enough not to generate false results. Further Gurkynack (2013) point out that most of the effects are seen within 10 minutes and they use a 20-minute window with 5 minutes before the release and 15 minutes after the release. Hence an event-window of 2 days could be considered a too long time interval, which could include effects that is based on other factors or events on the same day.

4.6.2 EVENT CLUSTERING

The study might be subject to some problems with event clustering, which appear when the events in question are clustered in time. The issue of event clustering could result in a decreased probability to identify the abnormal return that is related to the event (Peterson, 1989). The reason why this might be an issue is because the announcements of the money supply, M1, are published every week. Hence the market is well updated and aware of what the money supply will be next week and consequentially the surprises will be few. One could argue that we are only facing a well-informed market and not an event clustering issue.

Another problem regarding event clustering that might appear in the study is related to the dates of different macroeconomic news announcements. On some occasions there is some sort of news announcement the day after the PPI is announced. The unrelated effect from an independent event could hence be registered on the lagged interest rate. Further the CPI is often released within a few days after the PPI and the market participants would therefore already have adjusted their inflation expectations, resulting in a decreased gap between unanticipated and anticipated CPI.

4.6.3 ENDOGENEITY

There could also exist some issues with endogeneity in the regressions because of omitted variables and causality between the variables. The interest rate is affected by many different factors, not only by the money supply or the inflation, therefore one can assume that there are omitted variables. Further, a high level of inflation may lead the central bank to increase the interest rate, whilst a low interest rate might increase the level of inflation. This gives rise to the discussion of endogeneity, since the variables affect each other. The same could be questioned regarding the money supply, where a low interest rate increases the money demand and the spending which could increase the price level, i.e. the inflation, which in turn could influence the central bank to increase the interest rates. Hence, once again it is not a simple task to determine which effect comes first since the variables affect each other.

These effects should not however show any impact immediately in a normal environment, as it takes time for the money supply and inflation to adjust to interest rate changes. (Studenmund, 2011; Carlin & Soskice, 2006)

4.6.4 EXPECTATION MODELS

Additional complications of the study could arise regarding the determination of the anticipated variables. It could be the case that the expected inflation does not fully reflect the expected PPI or the CPI, which, in that case, would contribute to incorrect parameters. The expected money supply is instead obtained using an ARMA forecasting model, which also could give rise to some cumbersome results depending on the degree of which the model and the expectations of the market are aligned.

5.0 RESULT

In this chapter of the paper, the results of the performed regressions will be presented. In the first section the result from the entire sample will be shown, later the result of the subsamples that are divided into two groups: Before and after the global financial crisis will be displayed. Finally, the results of the regressions containing lagged variables will presented.

5.1 RESULT FROM THE ENTIRE SAMPLE

The result of the regressions that are conducted on the whole sample can be viewed below, the starting dates of the different variables vary in some degree and so does the starting date of the interest rate due to the availability of the data. In the column "Model Adjustments" the different adjustments to the model that account and correct for heteroskedasticity and serial correlation in the standard errors and the covariance are shown.

Announcement	Sample Period	No. of observations	No. of events	Interest rate	Model Adjustments	α_0	α_1	α_2	R^2
CPI	18/01/1990 - 30/03/2015	6573	302	ΔR5	None	0.001242 (0.4249)	-0.000499 (0.322)	-0.000290 (0.8109)	0.00016
	18/01/1990 - 30/03/2015	6573	302	ΔR10	None	0.000727 (0.4815)	-0.000313 (0.3500)	-0.000189 (0.8145)	0.00014
	15/10/1993 - 30/03/2015	5597	257	ΔR20	None	0.001097 (0.2471)	-0.000429 (0.1703)	-0.000420 (0.5538)	0.00040
	18/01/1990 - 30/03/2015	6573	302	ΔR30	None	0.000900 (0.2383)	-0.000356 (0.1498)	-0.000057 (0.9234)	0.00032
PPI	12/01/1990 - 30/03/2015	6577	302	ΔR5	HAC SE & Covariance	0.001666 (0.3041)	-0.000620 (0.2371)	0.001533 (0.0323)**	0.00126
	12/01/1990 - 30/03/2015	6577	302	ΔR10	HAC SE & Covariance	0.000973 (0.4017)	-0.000380 (0.3003)	0.001073 (0.0214)**	0.00135
	14/10/1993 - 30/03/2015	5598	257	ΔR20	White heteroskedasticity-consistent SE & Covariance	0.001283 (0.2236)	-0.000480 (0.1676)	0.000724 (0.0665)*	0.00122
	12/01/1990 - 30/03/2015	6577	302	ΔR30	HAC SE & Covariance	0.001100 (0.2155)	-0.000413 (0.1380)	0.000717 (0.0469)**	0.00133
Money Supply (M1)	04/02/1999 - 30/03/2015	4213	838	ΔR5	None	-0.000925 (0.5030)	0.000000 (0.6269)	0.000005 (0.9362)	0.00006
	04/02/1999 - 30/03/2015	4213	838	ΔR10	None	-0.000069 (0.9384)	-0.000000 (0.8639)	-0.000007 (0.8712)	0.00001
	04/02/1999 - 30/03/2015	4213	838	ΔR20	None	0.000174 (0.8006)	-0.000000 (0.5616)	-0.000011 (0.7240)	0.00011
	04/02/1999 - 30/03/2015	4213	838	ΔR30	None	0.000232 (0.7206)	-0.000000 (0.5121)	-0.000021 (0.4958)	0.00021

*Significant at a 10 % significance level, **Significant at a 5 % significance level, ***Significant at a 1 % significance level. P-values of the coefficients are displayed in parenthesis below the coefficients

ΔRi – is the daily change in the different Treasury bills.

Model Adjustments – modifies the model if it shows signs of heteroskedasticity and/or serial correlation

α0 is the constant coefficient, α1 is the coefficient of the anticipated change in the variables, and α2 is the coefficient of the unanticipated change.

Table 2. Results from the entire sample

The table is divided into three main sections, one for each of the independent variables. There are also 4 models in each main section, one model for each Treasury bill. ΔR5 is the model with the 5-year interest rate as a dependent variable. ΔR10 is the model with the 10-year interest rate as a dependent variable and so on.

a_0 is the constant in each model, a_1 is the coefficient of the unanticipated variable and a_2 is the coefficient for the anticipated variable.

The values in brackets below the constants and coefficients are the respective p-values. The p-values show the significance of the following hypothesis:

H_0: The events have no impact

H_a: The events may have impact

We can observe the effects of the anticipated variables and more importantly the unanticipated variables on the change in the interest rates from table 2. The results from the regressions indicate that none of the coefficients from CPI or Money Supply announcements have any significant impact on the returns of any of the interest rates. Hence, the null hypothesis of no impact cannot be rejected. In the models where the anticipated and unanticipated PPI are used as independent variables the coefficients of the unanticipated PPIs' effect on the interest rate are significant and the null hypothesis can be rejected. The coefficients of the anticipated PPI models are not significant. When using the return of the 5-, 10- and 30-year treasury bills the coefficient of the unanticipated PPI is significant at a 5 % significance level. When the 10-year Treasury bill is used the coefficient is significant at a 10 % level. In the table it is also possible to see that the coefficients have a positive sign indicating that a positive PPI surprise results in an increased interest rate. In the model where the change in the 5 year interest rate and the PPI is used, it can be seen that a 1 percentage point positive surprise in the PPI results in a 15.33 basis point increase in the continuously compounded return of the 5 year interest rate. Similarly a one percentage point increase in the PPI leads to a 10.73, 7.24 and 7.17 basis point increase in the continuously compounded return of the 10-, 20- and 30-year treasury bills respectively.

The models based on the 5- and 10-year Treasury bills showed signs of both serial correlation and heteroskedasticity therefore HAC standard errors and covariance were used to correct for these statistical issues. Using corrected standard errors does not affect the coefficients in the models, it only has an impact on the significance of these values. Nevertheless the coefficients which were significant before the corrections remained significant after as well. (Studenmund, 2011)

Further, the models where the 20- and the 30-year Treasury bills were used showed signs of heteroskedasticity and this was corrected for by using: White heteroskedasticity-consistent standard errors and covariance.

The R-square shows the total fit of each model, which indicates a low fit in all the models of the study (Studenmund, 2011). However this is not important since the study is not trying to predict or explain the interest rate returns in anyway. The purpose of the research is to find proof on the effects which unanticipated inflation and money supply may have on long-term interest rates. Hence all other factors which may or may not explain the interest rates are irrelevant for the purpose of this study.

5.2 RESULT FROM THE PRE GFC SAMPLE

The below table exhibits the results of the regressions that are performed on the sample data from before the GFC. The end date of the sample is the 30th of May 2008, for the reason motivated in the methodology chapter.

Announcement	Sample Period	No. of observations	No. of events	Interest rate	Model Adjustments	α_0	α_1	α_2	R^2
CPI	18/01/1990 - 30/05/2008	4792	221	ΔR5	None	-0.000307 (0.7927)	0.000042 (0.9119)	0.000290 (0.8313)	0.00001
	18/01/1990 - 30/05/2008	4792	221	ΔR10	None	0.000261 (0.7706)	-0.000136 (0.6449)	0.000538 (0.6063)	0.00009
	15/10/1993 - 30/05/2008	3816	176	ΔR20	None	0.000582 (0.5231)	-0.000221 (0.4751)	0.0000903 (0.9354)	0.00014
	18/01/1990 - 30/05/2008	4792	221	ΔR30	None	0.000329 (0.6335)	-0.000149 (0.5131)	0.000462 (0.5660)	0.00015
PPI	12/01/1990 - 30/05/2008	4796	221	ΔR5	HAC SE & Covariance	-0.000175 (0.9172)	0.000009 (0.9872)	0.000836 (0.1195)	0.00063
	12/01/1990 - 30/05/2008	4796	221	ΔR10	HAC SE & Covariance	0.000300 (0.8101)	-0.000141 (0.7252)	0.000690 (0.0747)*	0.00074
	14/10/1993 - 30/05/2008	3817	176	ΔR20	White heteroskedasticity-consistent SE & Covariance	0.000549 (0.6492)	-0.000205 (0.6151)	0.000566 (0.0698)*	0.00082
	12/01/1990 - 30/05/2008	4796	221	ΔR30	White heteroskedasticity-consistent SE & Covariance	0.000339 (0.7014)	-0.000146 (0.6149)	0.000551 (0.0564)*	0.00082
Money Supply (M1)	04/02/1999 - 30/05/2008	2432	482	ΔR5	None	-0.002669 (0.4993)	0.000002 (0.5191)	0.000014 (0.8434)	0.00018
	04/02/1999 - 30/05/2008	2432	482	ΔR10	None	-0.000827 (0.7738)	0.000001 (0.7922)	-0.000002 (0.9645)	0.00003
	04/02/1999 - 30/05/2008	2432	482	ΔR20	None	-0.000326 (0.8840)	0.000000 (0.9053)	0.000007 (0.8731)	0.00002
	04/02/1999 - 30/05/2008	2432	482	ΔR30	None	0.000122 (0.9549)	-0.000000 (0.9391)	0.000007 (0.8510)	0.00002

*Significant at a 10 % significance level, **Significant at a 5 % significance level, ***Significant at a 1 % significance level. P-values of the coefficients are displayed in parenthesis below the coefficients

ΔRi – is the daily change in the different Treasury bills.

Model Adjustments – modifies the model if it shows signs of heteroskedasticity and/or serial correlation

α0 is the constant coefficient, α1 is the coefficient of the anticipated change in the variables, and α2 is the coefficient of the unanticipated change.

Table 3. Results from the Pre GFC sample

Similar to the results of the entire sample, the coefficients for the unanticipated money supply and CPI have no significant effect on the return of any of the interest rates. The anticipated money supply and CPI did not either produce significant coefficients. With this sample the unanticipated PPI did not have a significant coefficient when regressed on the change in the 5-year Treasury bill.

For the 10-, 20- and 30-year Treasury bill on the other hand the coefficients showed positive and significant signs on a 10 % significance level. The impact on the change in interest rates based on a one percentage point change in PPI was 6.90, 5.66 and 5.51 basis points for the 10-, 20- and 30-year Treasury bills respectively.

5.3 RESULT FROM THE POST GFC SAMPLE

The table below shows the result of the 12 regressions that was run with the sample that contains data from after the GFC. The starting date of the sample is the 1st of April 2009, at which point the markets had started to recover.

Announcement	Sample Period	No. of observations	No. of events	Interest rate	Model Adjustments	α_0	α_1	α_2	R^2
CPI	01/04/2009 - 30/03/2015	1564	71	ΔR5	White heteroskedasticity-consistent SE & Covariance	0.006385 (0.2984)	-0.002187 (0.2685)	-0.004158 (0.0359)**	0.00263
	01/04/2009 - 30/03/2015	1564	71	ΔR10	White heteroskedasticity-consistent SE & Covariance	0.003471 (0.3376)	-0.001251 (0.2735)	-0.002914 (0.0147)**	0.00317
	01/04/2009 - 30/03/2015	1564	71	ΔR20	White heteroskedasticity-consistent SE & Covariance	0.002890 (0.3029)	-0.001071 (0.2264)	-0.002105 (0.0182)**	0.00286
	01/04/2009 - 30/03/2015	1564	71	ΔR30	White heteroskedasticity-consistent SE & Covariance	0.002462 (0.3424)	-0.000904 (0.2681)	-0.001819 (0.0212)**	0.00256
PPI	01/04/2009 - 30/03/2015	1564	71	ΔR5	White heteroskedasticity-consistent SE & Covariance	0.009703 (0.1096)	-0.003122 (0.1112)	0.003434 (0.0396)**	0.00475
	01/04/2009 - 30/03/2015	1564	71	ΔR10	White heteroskedasticity-consistent SE & Covariance	0.005582 (0.1186)	-0.001845 (0.1037)	0.001864 (0.0773)*	0.00392
	01/04/2009 - 30/03/2015	1564	71	ΔR20	None	0.004340 (0.1911)	-0.001479 (0.1641)	0.001079 (0.1155)	0.00266
	01/04/2009 - 30/03/2015	1564	71	ΔR30	White heteroskedasticity-consistent SE & Covariance	0.004005 (0.1173)	-0.001248 (0.1550)	0.001085 (0.1661)	0.00301
Money Supply (M1)	01/04/2009 - 30/03/2015	1564	313	ΔR5	None	-0.002226 (0.6423)	0.000001 (0.6552)	0.000113 (0.2990)	0.00798
	01/04/2009 - 30/03/2015	1564	313	ΔR10	None	0.000286 (0.9222)	-0.000000 (0.8606)	0.000072 (0.2760)	0.00079
	01/04/2009 - 30/03/2015	1564	313	ΔR20	None	0.000752 (0.7447)	-0.000000 (0.6458)	0.000042 (0.4224)	0.00057
	01/04/2009 - 30/03/2015	1564	313	ΔR30	None	0.001355 (0.5178)	-0.000001 (0.4444)	0.000025 (0.5988)	0.00057

*Significant at a 10 % significance level, **Significant at a 5 % significance level, ***Significant at a 1 % significance level. P-values of the coefficients are displayed in parenthesis below the coefficients

ΔRi – is the daily change in the different Treasury bills.

Model Adjustments – modifies the model if it shows signs of heteroskedasticity and/or serial correlation

α0 is the constant coefficient, α1 is the coefficient of the anticipated change in the variables, and α2 is the coefficient of the unanticipated change.

Table 4. Results from the Post GFC sample

The result of the regressions conducted on the sample after the GFC generate somewhat different results compared to the previous samples. The coefficients of the money supply are still insignificant for all four interest rates. It can however be observed that the coefficients of the unanticipated CPI has significant values at a 5 % level on each of the dependent variables. The coefficients of the unanticipated CPI are negative indicating that a positive CPI surprise has a negative impact on the change in the interest rate. A one percentage point increase in the CPI results in a negative change of: -41.58, -29.14, -21.05 and -18.19 basis points in the change of the 5-, 10-, 20- and 30-year treasury bonds. The regressions performed with CPI as independent variables showed signs of heteroskedasticity. This was corrected for by using

White heteroskedasticity-consistent standard errors and variance, the coefficients remained significant after the adjustment.

The coefficient of the unanticipated PPI when regressed on the change in the 5-year Treasury bill is significant on a 5 % level. A positive surprise of one percentage point results in a 34.34 basis points increase in the change of the 5-year Treasury bill. When regressed on the 10-year Treasury bill the coefficient is still significant however now at a 10 % significance level. The effects of a positive one-percentage point surprise in the PPI leads to an 18.64 basis point increase in the 10-year Treasury bill. Both the regressions when using the 5- and 10-year Treasury bills suggests presence of heteroskedasticity, hence the models were corrected by using White heteroskedasticity-consistent standard errors and covariance. When PPI was regressed on the 20-year interest rate, the coefficient of unanticipated PPI could not be proven to be significant. The final regression with PPI was conducted with the 30-year interest rate, which showed a significant coefficient on a 10 % level in the original regression. The model did however also show signs of heteroskedasticity, therefore the model was again adjusted by the use of White heteroskedasticity-consistent standard errors and covariance. After the adjustment the coefficient of the unanticipated PPI was no longer significant.

5.4 RESULT OF REGRESSIONS WITH LAGGED VARIABLES

The full results of the regressions where lagged variables are used are shown in appendix A. Lagged variables are used in order to determine if the market is efficient and adapts to the new information quickly or if the adaptation of the interest rate to inflation news is delayed to some extent. The lagged regression is used to test for the models in a broader event window of +1 day (after the event), hence only one lag is used.

Announcement	Sample Period	No. of observations	No. of events	Interest rate	Model Adjustments	α_0	α_1	α_2	R^2
CPI	02/04/2009 - 30/03/2015	1563	71	ΔR5	None	0.007995 (0.2483)	-0.002670 (0.2279)	-0.002563 (0.2820)	0.00171
	02/04/2009 - 30/03/2015	1563	71	ΔR10	None	0.004710 (0.2656)	-0.001605 (0.2355)	-0.000891 (0.5402)	0.00117
	02/04/2009 - 30/03/2015	1563	71	ΔR20	None	0.003935 (0.2380)	-0.001372 (0.1985)	-0.000606 (0.5971)	0.00126
	02/04/2009 - 30/03/2015	1563	71	ΔR30	None	0.003534 (0.2430)	-0.001216 (0.2090)	-0.000405 (0.6975)	0.00112
PPI	02/04/2009 - 30/03/2015	1563	71	ΔR5	White heteroskedasticity-consistent SE & Covariance	0.006069 (0.3163)	-0.002036 (0.2973)	-0.002945 (0.0126)**	0.00345
	02/04/2009 - 30/03/2015	1563	71	ΔR10	White heteroskedasticity-consistent SE & Covariance	0.003351 (0.3478)	-0.001172 (0.2988)	-0.001726 (0.0154)**	0.00315
	02/04/2009 - 30/03/2015	1563	71	ΔR20	White heteroskedasticity-consistent SE & Covariance	0.002905 (0.2928)	-0.001043 (0.2320)	-0.001184 (0.0253)**	0.00267
	02/04/2009 - 30/03/2015	1563	71	ΔR30	None	0.002483 (0.4101)	-0.000882 (0.3608)	-0.000942 (0.1304)	0.00212
Money Supply (M1)	02/04/2009 - 30/03/2015	1563	313	ΔR5	None	-0.001959 (0.6832)	8.32E-07 (0.6942)	3.81E-05 (0.7261)	0.00017
	02/04/2009 - 30/03/2015	1563	313	ΔR10	None	0.000420 (0.8859)	-2.83E-07 (0.8269)	5.20E-05 (0.4331)	0.00043
	02/04/2009 - 30/03/2015	1563	313	ΔR20	None	0.000917 (0.6914)	-5.36E-07 (0.5987)	3.63E-05 (0.4885)	0.00050
	02/04/2009 - 30/03/2015	1563	313	ΔR30	None	0.001474 (0.4823)	-7.57E-07 (0.4133)	3.53E-05 (0.4572)	0.00081

*Significant at a 10 % significance level, **Significant at a 5 % significance level, ***Significant at a 1 % significance level. P-values of the coefficients are displayed in parenthesis below the coefficients

ΔRi – is the daily change in the different Treasury bills.

Model Adjustments – modifies the model if it shows signs of heteroskedasticity and/or serial correlation

α0 is the constant coefficient, α1 is the coefficient of the anticipated change in the variables, and α2 is the coefficient of the unanticipated change.

Table 5. Results from the lagged Post GFC sample

The above table only shows the sample with the significant models from the lagged results where we can observe that three of the coefficients of the unanticipated PPI are significant at a 5 % significance level. The significant variables for the lags are the unanticipated PPI's effect on the change in the 5-, 10- and 20-year interest rate in the post GFC sample. The coefficients are negative, suggesting that a positive PPI surprise would have a negative impact on the interest rate the day after the announcement. A one percentage point positive surprise in the unanticipated PPI would result in a -29.45, -17.26 and -11.84 basis point change in the 5-, 10- and 20-year interest rate return. The extraordinarily aspect which can be observed is that we can see a significant effect in the 20-year interest rate return one day after the event, but not the day of the event.

6.0 ANALYSIS

In this part of the paper an analysis of the results will be conducted, were the results will be examined both independently and in relation to previous studies and theories. The focus will lie on the significant results whilst the insignificant results will be mentioned briefly. The outline of this section will follow the outline from the results chapter. This chapter will start by discussing the entire sample, then the pre and post samples and at last discuss any effects from the lagged model.

6.1 ANALYSIS OF THE ENTIRE SAMPLE

The results from the entire sample demonstrated that PPI as a proxy for unanticipated inflation had an effect on all of the interest rates, whilst CPI as a proxy did not have any significant results. This result is similar to the results of Urich & Wachtel (1981) whom also retrieve non-significant results from the CPI. The reason which the authors have put forwards for this occurrence is timing. The PPI announcements are always a few days before the CPI announcements, hence the markets would logically not retrieve any new information from the CPI announcements which isn't already delivered by the PPI announcements (Urich & Wachtel, 1981). The data used in this study exhibit the same timing traits and hence the same logic is applicable. The coefficients from the significant results are positive and hence it means that a positive surprise in the inflation gives a positive reaction (increase) in the interest rates. This result is in line with the Expected Inflation Hypothesis which explains the effects of direct inflation on the interest rates. As the results reveal significant effects on the long-term interest rates an inference can be made based on theory. The inference is that the PPI inflation surprise not only affects investors' immediate expectation on inflation but also their future (long-term) expectations on inflation (Cornell, 1983).

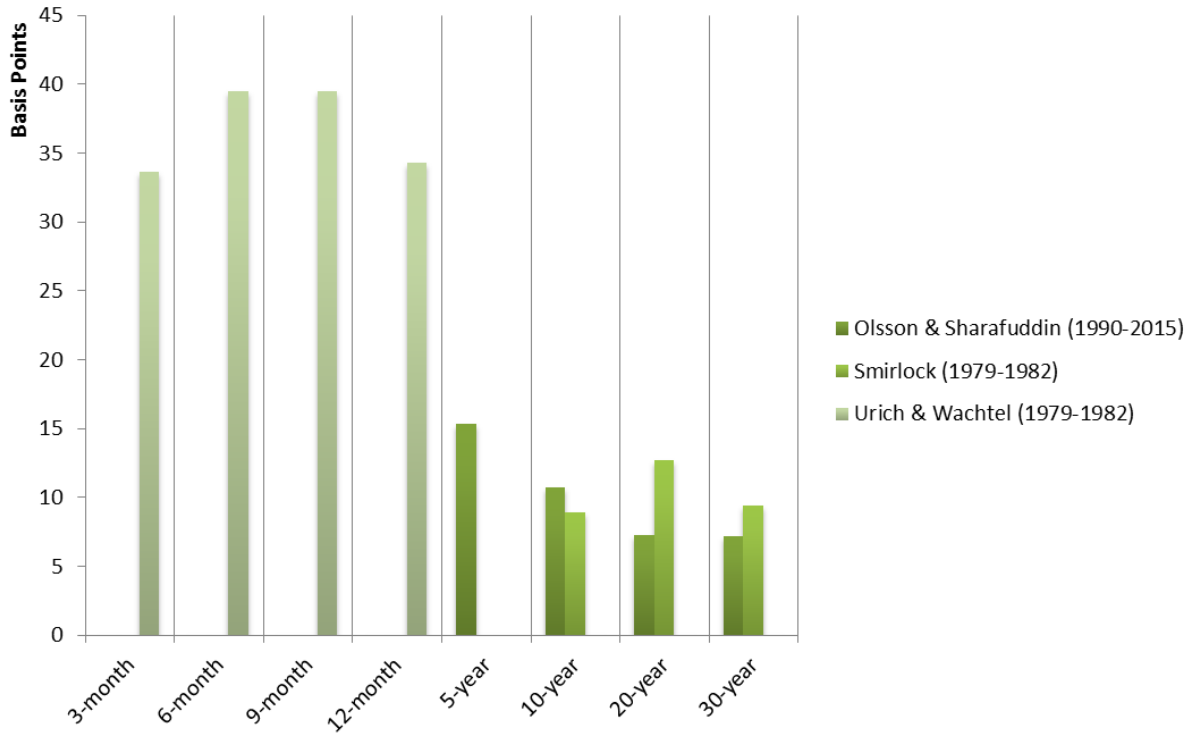

Figure 1. Comparison between studies: Number of basis point change in rates if a 1-percentage change in inflation occurs

As can be seen in figure 3, the magnitude of the effects which are exhibited in this study are quite small when compared to some of the effects from previous studies. This study registers effects of 15, 10, 7 and 7 basis points on the 5-, 10-, 20- and 30-year Treasury bills when there is a 1 percentage surprise in inflation. However the results are reasonable as most previous studies have examined the effects on short-term interest rates. These interest rates are more easily affected since only the temporary expectation on inflation needs to be altered, whilst for long-term interest rates the long-term (future) expectation on inflation needs to be altered (Cornell, 1983). The results show that as the time to maturity of the Treasury bill goes down the effects become larger. When compared to the results of Smirlock (1986), who also investigates the effects on long-term interest rates, a more analogous result can be seen. A fact to consider when observing the magnitude of the results is that an equal effect in basis points in a short-term and a long-term Treasury bill would affect the prices of the long-term Treasury bill to a greater extent, because of the compounding effect (Smirlock, 1986).

The results also show that anticipated inflation (a_1) has no significant effect on any of the interest rates and is hence not significantly different from zero. This result is in line with theory and previous results.

A significant result in this variable would suggest that the markets are inefficient and that investors and hence markets react to the anticipated component of the information announcements. Any other result than insignificant results in this variable would be alarming as it would suggest that the U.S market is inefficient as according to the EMH (Fama, 1970; Smirlock, 1986).

The research finds no significant results from the money supply models. Hence the results do not support the Policy Anticipation Hypothesis nor the Real Activity Hypothesis explained in the theory chapter (Cornell, 1983; Urich & Wachtel, 1981). Previous research did however find significant results in this variable and the reasons for the difference can be many. First and fir most the time difference in sample between previous research and this research is between 20-40 years, hence many factors could have changed. As this study is not qualitative in nature, the explanations are only speculations. Nevertheless the most probable reason for the difference is that money supply announcements do not alter the markets long-term expectations on economic policy and output as explained in the real activity and policy anticipation hypothesis. Hence money supply has no effect on the long-term interest rates in this sample (Cornell, 1983; Urich & Wachtel, 1981). Another potential explanation for the non-significant results in the money supply announcements is that the forecasting model which is used (ARMA-model) does not reflect the market consensus of expected money supply correctly, this would create insignificant results. However Urich & Wachtel (*1981*) found that the ARMA model showed similar results as a market survey of the investor expectations on the money supply. The last potential explanation could be the close time interval between the (weekly) money supply announcements. The proximity could make the investors and market better forecast the money supply and hence the room for any surprises would be small. This issue is called event clustering (Peterson, 1989).

When analysing the result with regard to the Efficient Market Hypothesis no clear conclusions can be drawn on which category of efficiency the market is in, however there are some indications. The unanticipated PPI has a significant effect on the interest rate, which indicates that the markets are not “strongly efficient”. The variables of CPI and Money Supply are on the other hand not significant and the reason for this is unclear. One explanation could be that the market already incorporated the change from the variables in the interest rates, which would imply a strongly efficient market since the bond prices would then incorporate insider information, however this is not likely.

The result do nevertheless imply that the market is not "weakly efficient" since the coefficient of the anticipated variables are insignificant, hence implying that the market expectations are incorporated in the bond prices, resulting in a semi-efficient market. (Fama, 1970)

6.2 ANALYSIS OF PRE GFC

When dividing the sample and analysing the results from before the GFC we exhibit very similar results to the results from the entire sample. Since the sample from before the GFC is significantly larger than the sample from after the GFC it is reasonable to see this resemblance between the two samples. The reasoning and analysis made above applies to the results in this section. Hence an analysis will be made on the differences in the results from the samples. As this study is unique in its time frame, a comparison to previous studies is not possible in terms of the effects from before and after the GFC.

The difference which can be comprehended from the samples is that the results become less significant pre GFC. The unanticipated inflation in the PPI model on the 5-year interest rates which had a significant effect before can no longer be considered to be significant at a 10 % level. Based on theory (Efficient Inflation Hypothesis) we make the conclusion that the unanticipated inflation is not as strong in altering the investor's long-term expectations of inflation. This makes all values less significant and the value on the 5-year interest rate happens to be pushed outside of the 10 % level boundary. (Cornell, 1983)

In the next section a comparison will be made between the pre and post GFC samples and hence shed more light into the results from these sections.

6.3. ANALYSIS OF POST GFC

As mentioned in the last section the sample from the post GFC is smaller and hence will show results that are distinctive to a period right after a financial crisis. As we move further away from the GFC of 2008 it would be interesting to see how these results alter.

The result which is clearly the biggest surprise in the post GFC sample (when compared to both the entire sample and pre GFC sample) is the sudden significance in the CPI models over the PPI models. The reasoning for the fact that PPI models were significant over CPI models was the simple logic that PPI announcements were released a few days before CPI

announcements. This fact has not changed after the GFC. Yet still investors and markets have now started to depend and react to CPI announcements more. However when the coefficients are examined, negative values are observed which goes against the fisher equation and hence theory. This would suggest that a positive surprise in the unanticipated inflation would lead to a decrease in the long-term interest rates which is highly unreasonable. What this result indicates is that the sample is suffering from a causality problem. This means that the inflation is not affecting the interest rates but rather the other way around. Therefore a decrease in the interest rates would increase output and hence inflation. Since the U.S. and the entire globe was under financial distress during large parts of this time period, the federal reserve held interest rates low by intervening the markets, something which they are still doing to some extent. It is however not possible to prove causality using regression analysis. Therefore the test regarding this issue is instead for Granger causality. The results of the tests are disclosed in appendix E. The Granger causality tests whether one of the time series regularly changes before the other time series. This makes it possible to interpret which of the series that affect the other. The result of the Granger causality test on the significant regressions in the post GFC sample indicated that the change in the CPI follows the change in interest rate, whilst the change in the Treasury bills seem to come after the change in PPI. Because of these governmental interventions the strong causality after the financial crisis makes sense. However it should be noted that granger causality only gives us indications and does not prove causality in anyway. (Studenmund, 2011) (federalreserve.gov, 2015).

In addition we can observe that the PPI models for the 20- and 30-year interest rates show an insignificant unanticipated inflation. This result indicates a clear difference between the results pre and post the GFC. As causality seems to be a greater factor after the financial crisis due to reasons enclosed above, the differences are not unreasonable. Based on these results none of the theories can neither be supported nor rejected after the GFC.

6.4 ANALYSIS OF LAGGED MODELS

The lagged regressions are conducted in order to examine the event window of +1 day in this study. The +1 event day can reveal the efficiency and timing of the market in incorporating the information from this specific type of macroeconomic announcements. The graphs below show how the effects from the variables evolve from day 0 to +1 in the event window cumulatively, any insignificant coefficient will be registered as 0.

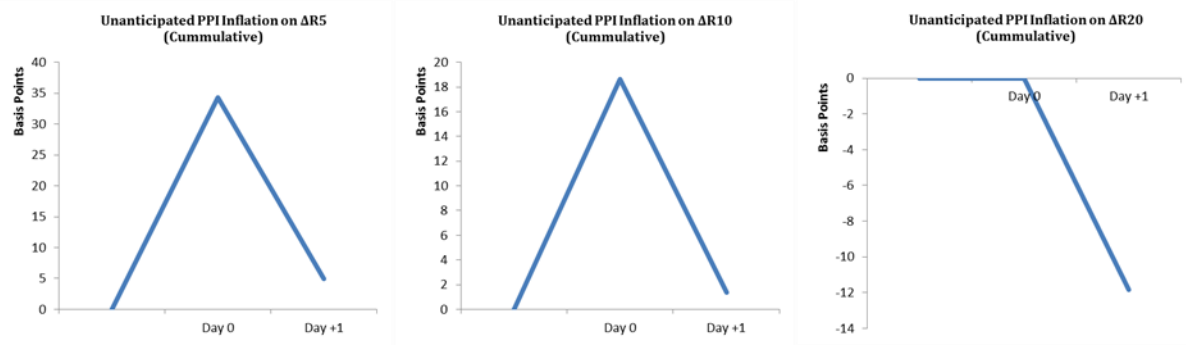

Figure 2. Event Window: Cumulative basis point change in interest rate from day 0 to day +1

The graphs show the only three models which showed significant values in the day after the event. All three of the models are PPI models from the post GFC sample. The rest of the nine models exhibit no significant values when lagged, this is true for all three samples (Entire sample, Pre GFC and Post GFC).

The change on both the 5- and 10-year Treasury bill from figure 2 shows a cumulative impact, which increases and then decreases the day after the event. The change on the 20-year Treasury bill shows a negative reaction the day after the event with no significant reaction on the day of the event.

At first glance this indicates an overreaction in the data. However after examining the event calendar it is noticed that after the GFC, PPI announcements are frequently followed by some other macroeconomic news announcement the day after, often CPI announcements. This explains the significant lags in PPI announcements after the GFC. From this notion it is discovered that the PPI data post GFC is suffering from event clustering. Unfortunately there is no way to distinguish the effects apart and thus no conclusion can be drawn from the lagged results of the PPI models post GFC. (Peterson, 1989)

Based on the facts presented above the overall conclusion which can be made from the regressions on the +1 day event is that the markets show weak signs of inefficiency and do not react after the announcements. The markets are thus quick to react and in this sense efficient.

7.0 CONCLUSION

When studying the effects of unanticipated inflation on the long-term interest rates of Treasury bills, it can be concluded that they do have an impact on the interest rates in the case of the U.S market, however these effects have limitations. The effects originate from PPI announcements with no significant effects being registered from the CPI and Money Supply announcements. Thus we can conclude that the effects arise from the inflation channel and not from a secondary channel as the money supply. The PPI is the significant channel as it is announced before the CPI. Further the study shows that the magnitude of the effects decreases with the maturity of the Treasury bills. The effect on interest rates of a 30-year Treasury bill is much less than the effect on a 5-year one. However the price of the 30-year Treasury bill is much more sensitive to change because of the compounding effect than the ones with shorter maturity. When examining the effects pre and post the GFC it can be concluded that the unanticipated inflation has a significantly smaller effect after the crisis. The reason for this is believed to be the interventions by the government to keep the interest rates low. Hence a causality issue arises where the interest rates affect the inflation instead.

This specific area of research has not been conducted for decades. Therefore this study is practically contributing to the existing literature by updating the empirical knowledge in the case of the U.S markets. The study is also providing the market with knowledge and insight into how these specific securities react to the new information and if the market's reaction is rational. Further the study also provides evidence in the differences in effects pre and post the GFC. Theoretically the study is contributing to existing literature by examining how relevant the theoretical theory is in explaining the reactions to these announcements. The research supports the efficient inflation hypothesis while not finding evidence to back up the policy anticipation and real activity hypothesis.

If we recall the introduction, and the discussion on interest rates and policymakers intervening, we can conclude that unanticipated inflation does have an impact on the interest rates even with inflation targeting being in place. However the magnitude of this effect can change through time depending on the financial climate. In times of distress when policymakers intervene much more heavily, the effects diminish.

As a suggestion for further research we would find it interesting to conduct the study using intraday data, since this would register the effects much more clearly and also exhibit the efficiency of the market at a more detailed level. This study has provided evidence on how the unanticipated inflation and money supply affects interest rates, which is a quantitative study in nature, therefore a qualitative approach on why they react the way they do would be interesting in order not to speculate on the reasons. This would include a qualitative approach of either surveying or interviewing analysts and major market participant on their logic behind the actions which they take during inflation and money supply announcements. This type of study would perhaps move the topic to the area of behavioural finance in order to explain the market rationale. Finally the research area could be extended to other markets in Europe and Asia in order to examine the comparability across different markets.

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9.0 APPENDIX

9.1 APPENDIX A – LAGGED RESULTS

Entire sample						
	Interest rate	Model adjustment	a0	a1	a2	R2
CPI	5Y	None	0.001692 (0.2769)	-0.000659 (0.1908)	-0.001963 (0.1049)	0.000687
	10Y	None	0.001111 (0.2823)	-0.000440 (0.1884)	-0.000208 (0.7956)	0.000278
	20Y	None	0.001402 (0.1391)	0.000525 (0.0932)	0.000232 (0.7433)	0.000521
	30Y	None	0.001249 (0.1016)	-0.000470 (0.0573)	0.000247 (0.6772)	0.000568
	Interest rate	Model adjustment	a0	a1	a2	R2
PPI	5Y	None	0.000991 (0.5228)	-0.000421 (0.4024)	-0.000578 (0.3078)	0.000292
	10Y	None	0.000625 (0.5438)	-0.000278 (0.4039)	-7.80E-05 (0.8358)	0.000119
	20Y	None	0.000949 (0.3152)	-0.000377 (0.2266)	-7.63E-05 (0.8129)	0.000283
	30Y	None	0.000807 (0.2885)	-0.000324 (0.1884)	7.03E-05 (0.8003)	0.000266
	Interest rate	Model adjustment	a0	a1	a2	R2
M1	5Y	None	-0.000941 (0.4960)	3.99E-0.7 (0.6205)	2.21E-0.5 (0.7309)	0.000087
	10Y	None	-8.18E-05 (0.9297)	-8.27E-08 (0.8738)	1.50E-05 (0.7171)	0.000037
	20Y	None	0.000170 (0.8057)	-2.31E-07 (0.5650)	1.60E-05 (0.6166)	0.000138
	30Y	None	0.000230 (0.7231)	-2.47E-07 (0.5133)	1.52E-05 (0.6136)	0.000162
PRE GFC sample						
	Interest rate	Model adjustment	a0	a1	a2	R2
CPI	5Y	None	-0.000207 (0.8594)	7.17E-06 (0.9852)	-0.000356 (0.7940)	0.000014
	10Y	None	0.000330 (0.7133)	-0.000161 (0.5861)	-0.000395 (0.7052)	0.000097
	20Y	None	0.000614 (0.5014)	-0.000233 (0.4521)	-0.000206 (0.8530)	0.000157
	30Y	None	0.000404 (0.5588)	-0.000176 (0.4403)	-0.000604 (0.4530)	0.000258
	Interest rate	Model adjustment	a0	a1	a2	R2
PP1	5Y	None	-0.000232 (0.8417)	1.97E-05 (0.9591)	0.000121 (0.8022)	0.000014
	10Y	None	0.000311 (0.7273)	-0.000149 (0.6112)	0.000295 (0.4262)	0.000172
	20Y	None	0.000576 (0.5254)	-0.000218 (0.4798)	0.000247 (0.4617)	0.000251
	30Y	None	0.000333 (0.6278)	-0.000147 (0.5161)	0.000278 (0.3312)	0.000264
	Interest rate	Model adjustment	a0	a1	a2	R2
M1	5Y	None	-0.002766 (0.4840)	2.07E-06 (0.5065)	-3.75E-05 (0.6067)	0.000304
	10Y	None	-0.000964 (0.7376)	6.98E-07 (0.7589)	-3.35E-05 (0.5282)	0.000210
	20Y	None	-0.000394 (0.8600)	2.54E-07 (0.8854)	-3.09E-05 (0.4524)	0.000246
	30Y	None	3.02E-05 (0.9888)	-6.47E-08 (0.9697)	-1.61E-05 (0.6859)	0.000068
POST GFC sample						
	Interest rate	Model adjustment	a0	a1	a2	R2
CPI	5Y	None	0.007995 (0.2483)	-0.002670 (0.2279)	-0.002563 (0.2820)	0.001713
	10Y	None	0.004710 (0.2656)	-0.001605 (0.2355)	-0.000891 (0.5402)	0.001165
	20Y	None	0.003935 (0.2380)	-0.001372 (0.1985)	-0.000606 (0.5971)	0.001260
	30Y	None	0.003534 (0.2430)	-0.001216 (0.2090)	-0.000405 (0.6975)	0.001124
	Interest rate	Model adjustment	a0	a1	a2	R2
PPI	5Y	White	0.006069 (0.3163)	-0.002036 (0.2973)	-0.002945 (0.0126)**	0.003446
	10Y	White	0.003351 (0.3478)	-0.001172 (0.2988)	-0.001726 (0.0154)**	0.003154
	20Y	White	0.002905 (0.2928)	-0.001043 (0.2320)	-0.001184 (0.0253)**	0.002668
	30Y	None	0.002483 (0.4101)	-0.000882 (0.3608)	-0.000942 (0.1304)	0.002118
	Interest rate	Model adjustment	a0	a1	a2	R2
M1	5Y	None	-0.001959 (0.6832)	8.32E-07 (0.6942)	3.81E-05 (0.7261)	0.000171
	10Y	None	0.000420 (0.8859)	-2.83E-07 (0.8269)	5.20E-05 (0.4331)	0.000433
	20Y	None	0.000917 (0.6914)	-5.36E-07 (0.5987)	3.63E-05 (0.4885)	0.000503
	30Y	None	0.001474 (0.4823)	-7.57E-07 (0.4133)	3.53E-05 (0.4572)	0.000813

Table 3. Lagged regression results for all samples

9.2 APPENDIX B – ARMA-MODEL

	AIC	SBIC	HQIC
ARMA(0,0)	15.35244	15.35641	15.35392
ARMA(0,1)	14.01701	14.02495	14.01999
ARMA(1,0)	7.988878	7.996822	7.991858
ARMA(1,1)	7.923991	7.935908	7.928462
ARMA(0,2)	12.84093	12.85284	12.8454
ARMA(1,2)	7.883995	7.899883	7.889956
ARMA(2,0)	7.953965	7.965889	7.958439
ARMA(2,1)	7.892186	7.908084	7.898151
ARMA(2,2)	7.885893	7.905766	7.893349
ARMA(0,3)	12.22928	12.24516	12.23524
ARMA(1,3)	7.884932	7.904793	7.892383
ARMA(2,3)	7.883423	7.90727	7.89237
ARMA(3,0)	7.909969	7.925877	7.915938
ARMA(3,1)	7.884366	7.904251	7.891827
ARMA(3,2)	7.879972	7.903834	7.888925
ARMA(3,3)	7.885481	7.91332	7.895926
ARMA(0,4)	11.28242	11.30227	11.28986
ARMA(1,4)	7.883332	7.907164	7.892273
ARMA(2,4)	7.884696	7.912517	7.895134
ARMA(3,4)	7.873395	7.905211	7.885333
ARMA(4,4)	7.875245	7.911061	7.888684
ARMA(4,0)	7.891738	7.911636	7.899204
ARMA(4,1)	7.885455	7.909332	7.894414
ARMA(4,2)	7.885212	7.913069	7.895664
ARMA(4,3)	7.881055	7.912891	7.893
ARMA(5,0)	7.889124	7.913016	7.898089
ARMA(5,1)	7.887473	7.915347	7.897932
ARMA(5,2)	7.886135	7.917991	7.898088
ARMA(5,3)	7.87512	7.910958	7.888567
ARMA5,4)	7.875995	7.915815	7.890937
ARMA(5,5)	7.865105	7.908906	7.88154
ARMA(0,5)	10.78429	10.80811	10.79323
ARMA(1,5)	7.883389	7.911194	7.89382
ARMA(2,5)	7.884379	7.916175	7.896309
ARMA(3,5)	7.874757	7.910551	7.888187
ARMA(4,5)	7.863578	7.903373	7.87851

Table 7. IC Table

Correlogram of M1

Date: 04/27/15 Time: 18:02
Sample: 4/04/1990 3/18/2015
Included observations: 1303

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.996	0.996	1294.9	0.000
		2	0.992	0.007	2579.8	0.000
		3	0.987	-0.001	3855.0	0.000
		4	0.983	0.004	5120.4	0.000
		5	0.979	-0.004	6376.2	0.000
		6	0.975	0.002	7622.3	0.000
		7	0.971	-0.012	8858.8	0.000
		8	0.967	0.023	10086.	0.000
		9	0.963	0.007	11304.	0.000
		10	0.959	-0.015	12513.	0.000
		11	0.955	0.002	13714.	0.000
		12	0.951	0.013	14905.	0.000
		13	0.947	-0.014	16087.	0.000
		14	0.943	-0.017	17260.	0.000
		15	0.939	0.002	18424.	0.000
		16	0.935	0.017	19579.	0.000
		17	0.931	-0.013	20725.	0.000
		18	0.927	0.006	21863.	0.000
		19	0.923	-0.002	22992.	0.000
		20	0.919	-0.023	24111.	0.000
		21	0.915	0.011	25222.	0.000
		22	0.911	0.009	26324.	0.000
		23	0.907	-0.014	27418.	0.000
		24	0.903	-0.008	28503.	0.000
		25	0.899	0.000	29578.	0.000
		26	0.895	-0.001	30646.	0.000
		27	0.891	-0.013	31704.	0.000
		28	0.887	0.008	32753.	0.000
		29	0.883	0.013	33795.	0.000
		30	0.879	-0.008	34827.	0.000
		31	0.875	0.007	35852.	0.000
		32	0.871	-0.011	36868.	0.000
		33	0.867	-0.027	37875.	0.000
		34	0.863	0.000	38874.	0.000
		35	0.859	-0.011	39863.	0.000
		36	0.855	-0.008	40844.	0.000

Figure 3. Correlogram

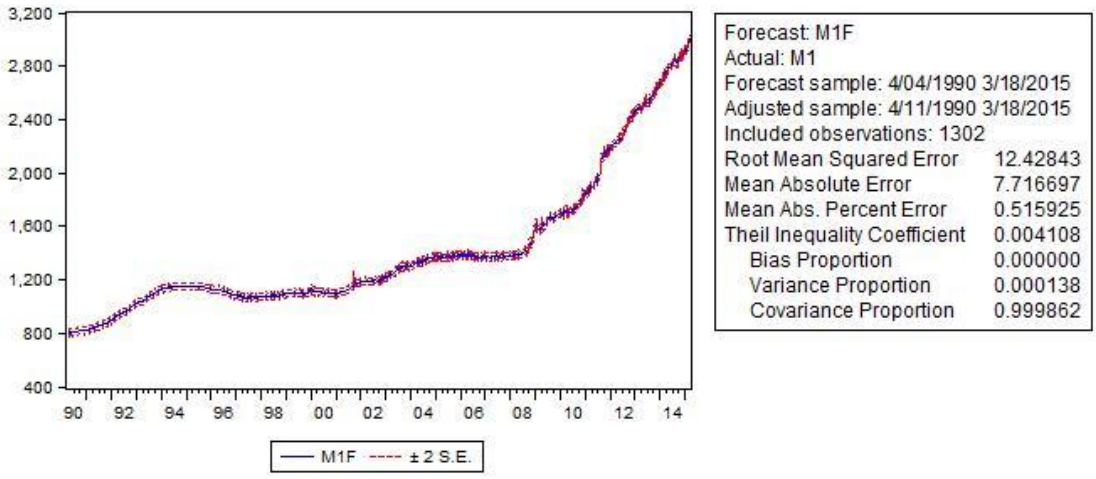

Figure 4. Forecasting graph

Null Hypothesis: M1 has a unit root
Exogenous: Constant
Lag Length: 14 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		4.761148	1.0000
Test critical values:	1% level	-3.435215	
	5% level	-2.863576	
	10% level	-2.567904	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(M1)
Method: Least Squares
Date: 04/24/15 Time: 10:34
Sample (adjusted): 7/18/1990 3/18/2015
Included observations: 1288 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
M1(-1)	0.003915	0.000822	4.761148	0.0000
D(M1(-1))	-0.299664	0.028048	-10.68389	0.0000
D(M1(-2))	-0.236532	0.028865	-8.194556	0.0000
D(M1(-3))	-0.138841	0.029611	-4.688856	0.0000
D(M1(-4))	-0.076857	0.029675	-2.589972	0.0097
D(M1(-5))	-0.064854	0.029756	-2.179548	0.0295
D(M1(-6))	0.014718	0.029755	0.494656	0.6209
D(M1(-7))	0.023511	0.029758	0.790056	0.4296
D(M1(-8))	0.113517	0.029849	3.803035	0.0001
D(M1(-9))	0.068366	0.030015	2.277747	0.0229
D(M1(-10))	0.037229	0.030035	1.239500	0.2154
D(M1(-11))	-0.111074	0.029974	-3.705705	0.0002
D(M1(-12))	-0.012127	0.029910	-0.405447	0.6852
D(M1(-13))	0.196192	0.029148	6.730782	0.0000
D(M1(-14))	0.113653	0.028350	4.008978	0.0001
C	-3.244594	1.073517	-3.022397	0.0026

R-squared	0.193775	Mean dependent var	1.681832
Adjusted R-squared	0.184268	S.D. dependent var	13.25931
S.E. of regression	11.97553	Akaike info criterion	7.815952
Sum squared resid	182421.7	Schwarz criterion	7.880062
Log likelihood	-5017.473	Hannan-Quinn criter.	7.840018
F-statistic	20.38157	Durbin-Watson stat	2.001724
Prob(F-statistic)	0.000000		

Table 8. Augmented Dickey-Fuller test

Dependent Variable: M1
Method: Least Squares
Date: 05/03/15 Time: 14:29
Sample (adjusted): 4/11/1990 3/18/2015
Included observations: 1302 after adjustments
Convergence achieved after 11 iterations
MA Backcast: 3/28/1990 4/04/1990

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	835.0232	95.40022	8.752844	0.0000
AR(1)	1.002873	0.000352	2850.815	0.0000
MA(1)	-0.281528	0.027259	-10.32770	0.0000
MA(2)	-0.191675	0.027278	-7.026857	0.0000

R-squared	0.999432	Mean dependent var	1420.158
Adjusted R-squared	0.999430	S.D. dependent var	521.5167
S.E. of regression	12.44757	Akaike info criterion	7.883995
Sum squared resid	201114.6	Schwarz criterion	7.899883
Log likelihood	-5128.481	Hannan-Quinn criter.	7.889956
F-statistic	760810.8	Durbin-Watson stat	1.988645
Prob(F-statistic)	0.000000		

Inverted AR Roots	1.00	
	Estimated AR process is nonstationary	
Inverted MA Roots	.60	-.32

Table 9. ARMA(1,2) Model

9.3 APPENDIX C – SUPPORTING MATERIAL FOR ENTIRE SAMPLE

Dependent Variable: _5YR
Method: Least Squares
Date: 05/06/15 Time: 16:08
Sample: 1/12/1990 3/30/2015
Included observations: 6577
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 11.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001666	0.001621	1.027798	0.3041
EXPECTED_INFLATION	-0.000620	0.000524	-1.182417	0.2371
PPI_SURPRISE	0.001533	0.000716	2.141122	0.0323

R-squared	0.001260	Mean dependent var	-0.000263
Adjusted R-squared	0.000956	S.D. dependent var	0.023263
S.E. of regression	0.023252	Akaike info criterion	-4.684415
Sum squared resid	3.554198	Schwarz criterion	-4.681317
Log likelihood	15407.70	Hannan-Quinn criter.	-4.683344
F-statistic	4.145809	Durbin-Watson stat	2.040570
Prob(F-statistic)	0.015872	Wald F-statistic	2.605421
Prob(Wald F-statistic)	0.073948		

Table 10. Final regression for PPI against 5-year rates

Dependent Variable: _10YR
Method: Least Squares
Date: 05/06/15 Time: 16:23
Sample: 1/12/1990 3/30/2015
Included observations: 6577
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 11.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000973	0.001161	0.838662	0.4017
EXPECTED_INFLATION	-0.000380	0.000367	-1.035779	0.3003
PPI_SURPRISE	0.001073	0.000466	2.301723	0.0214

R-squared	0.001353	Mean dependent var	-0.000215
Adjusted R-squared	0.001049	S.D. dependent var	0.015445
S.E. of regression	0.015437	Akaike info criterion	-5.503626
Sum squared resid	1.566617	Schwarz criterion	-5.500528
Log likelihood	18101.67	Hannan-Quinn criter.	-5.502555
F-statistic	4.453919	Durbin-Watson stat	1.972478
Prob(F-statistic)	0.011668	Wald F-statistic	2.874701
Prob(Wald F-statistic)	0.056504		

Table 11. Final regression for PPI against 5-year rates

Dependent Variable: _20YR
Method: Least Squares
Date: 05/06/15 Time: 16:56
Sample (adjusted): 10/14/1993 3/30/2015
Included observations: 5598 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001283	0.001055	1.217052	0.2236
EXPECTED_INFLATION	-0.000480	0.000348	-1.380205	0.1676
PPI_SURPRISE	0.000724	0.000394	1.835094	0.0665

R-squared	0.001220	Mean dependent var	-0.000171
Adjusted R-squared	0.000863	S.D. dependent var	0.012811
S.E. of regression	0.012805	Akaike info criterion	-5.877390
Sum squared resid	0.917434	Schwarz criterion	-5.873837
Log likelihood	16453.82	Hannan-Quinn criter.	-5.876152
F-statistic	3.416916	Durbin-Watson stat	1.986283
Prob(F-statistic)	0.032882	Wald F-statistic	2.385160
Prob(Wald F-statistic)	0.092168		

Table 12. Final regression for PPI against 20-year rates

Dependent Variable: _30YR
Method: Least Squares
Date: 05/06/15 Time: 17:02
Sample: 1/12/1990 3/30/2015
Included observations: 6577
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 11.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001100	0.000888	1.238581	0.2155
EXPECTED_INFLATION	-0.000413	0.000278	-1.483335	0.1380
PPI_SURPRISE	0.000717	0.000361	1.987866	0.0469

R-squared	0.001327	Mean dependent var	-0.000176
Adjusted R-squared	0.001023	S.D. dependent var	0.011410
S.E. of regression	0.011404	Akaike info criterion	-6.109180
Sum squared resid	0.855015	Schwarz criterion	-6.106083
Log likelihood	20093.04	Hannan-Quinn criter.	-6.108110
F-statistic	4.367499	Durbin-Watson stat	1.960045
Prob(F-statistic)	0.012720	Wald F-statistic	2.630921
Prob(Wald F-statistic)	0.072088		

Table 13. Final regression for PPI against 30-year rates

9.4 APPENDIX D – SUPPORTING MATERIAL FOR PRE GFC SAMPLE

Dependent Variable: _10YR
Method: Least Squares
Date: 05/07/15 Time: 17:00
Sample: 1/12/1990 5/30/2008
Included observations: 4796
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 10.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000300	0.001247	0.240259	0.8101
EXPECTED_INFLATION	-0.000141	0.000400	-0.351592	0.7252
PPI_SURPRISE	0.000690	0.000387	1.782458	0.0747

R-squared	0.000741	Mean dependent var	-0.000142
Adjusted R-squared	0.000324	S.D. dependent var	0.011012
S.E. of regression	0.011010	Akaike info criterion	-6.179434
Sum squared resid	0.580988	Schwarz criterion	-6.175384
Log likelihood	14821.28	Hannan-Quinn criter.	-6.178011
F-statistic	1.776202	Durbin-Watson stat	1.934875
Prob(F-statistic)	0.169391	Wald F-statistic	1.613641
Prob(Wald F-statistic)	0.199269		

Table 14. Final regression for PPI against 10-year rates

Dependent Variable: _20YR
Method: Least Squares
Date: 05/07/15 Time: 17:04
Sample (adjusted): 10/14/1993 5/30/2008
Included observations: 3817 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000549	0.001206	0.454966	0.6492
EXPECTED_INFLATION	-0.000205	0.000408	-0.502887	0.6151
PPI_SURPRISE	0.000566	0.000312	1.814003	0.0698

R-squared	0.000820	Mean dependent var	-6.31E-05
Adjusted R-squared	0.000296	S.D. dependent var	0.009307
S.E. of regression	0.009306	Akaike info criterion	-6.515547
Sum squared resid	0.330293	Schwarz criterion	-6.510637
Log likelihood	12437.92	Hannan-Quinn criter.	-6.513802
F-statistic	1.564309	Durbin-Watson stat	1.979984
Prob(F-statistic)	0.209367	Wald F-statistic	1.688868
Prob(Wald F-statistic)	0.184867		

Table 15. Final regression for PPI against 20-year rates

Dependent Variable: _30YR
Method: Least Squares
Date: 05/07/15 Time: 17:11
Sample: 1/12/1990 5/30/2008
Included observations: 4796
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000339	0.000885	0.383438	0.7014
EXPECTED_INFLATION	-0.000146	0.000289	-0.503060	0.6149
PPI_SURPRISE	0.000551	0.000289	1.908350	0.0564

R-squared	0.000819	Mean dependent var	-0.000113
Adjusted R-squared	0.000402	S.D. dependent var	0.008496
S.E. of regression	0.008494	Akaike info criterion	-6.698225
Sum squared resid	0.345827	Schwarz criterion	-6.694174
Log likelihood	16065.34	Hannan-Quinn criter.	-6.696802
F-statistic	1.964921	Durbin-Watson stat	1.974314
Prob(F-statistic)	0.140280	Wald F-statistic	1.869228
Prob(Wald F-statistic)	0.154355		

Table 16. Final regression for PPI against 30-year rates

9.5 APPENDIX E – SUPPORTING MATERIAL FOR POST GFC SAMPLE

Dependent Variable: _5YR
Method: Least Squares
Date: 05/07/15 Time: 16:25
Sample: 4/01/2009 3/30/2015
Included observations: 1564
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.006385	0.006138	1.040123	0.2984
EXPECTED_INFLATION	-0.002187	0.001976	-1.106936	0.2685
CPI_SURPISE	-0.004158	0.001980	-2.099568	0.0359

R-squared	0.002630	Mean dependent var	-0.000108
Adjusted R-squared	0.001352	S.D. dependent var	0.036364
S.E. of regression	0.036340	Akaike info criterion	-3.789901
Sum squared resid	2.061404	Schwarz criterion	-3.779629
Log likelihood	2966.703	Hannan-Quinn criter.	-3.786083
F-statistic	2.058032	Durbin-Watson stat	2.061986
Prob(F-statistic)	0.128051	Wald F-statistic	2.920887
Prob(Wald F-statistic)	0.054180		

Table 17. Final regression for CPI against 5-year rates

Dependent Variable: _10YR
Method: Least Squares
Date: 05/07/15 Time: 16:32
Sample: 4/01/2009 3/30/2015
Included observations: 1564
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003471	0.003619	0.959166	0.3376
EXPECTED_INFLATION	-0.001251	0.001142	-1.095407	0.2735
CPI_SURPISE	-0.002914	0.001193	-2.441630	0.0147

R-squared	0.003174	Mean dependent var	-0.000207
Adjusted R-squared	0.001897	S.D. dependent var	0.022210
S.E. of regression	0.022189	Akaike info criterion	-4.776502
Sum squared resid	0.768577	Schwarz criterion	-4.766231
Log likelihood	3738.225	Hannan-Quinn criter.	-4.772684
F-statistic	2.485090	Durbin-Watson stat	2.014679
Prob(F-statistic)	0.083648	Wald F-statistic	3.735246
Prob(Wald F-statistic)	0.024081		

Table 18. Final regression for CPI against 10-year rates

Dependent Variable: _20YR
Method: Least Squares
Date: 05/07/15 Time: 16:37
Sample: 4/01/2009 3/30/2015
Included observations: 1564
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002890	0.002804	1.030651	0.3029
EXPECTED_INFLATION	-0.001071	0.000885	-1.210166	0.2264
CPI_SURPISE	-0.002105	0.000890	-2.363842	0.0182

R-squared	0.002857	Mean dependent var	-0.000283
Adjusted R-squared	0.001580	S.D. dependent var	0.017516
S.E. of regression	0.017502	Akaike info criterion	-5.251084
Sum squared resid	0.478167	Schwarz criterion	-5.240812
Log likelihood	4109.348	Hannan-Quinn criter.	-5.247265
F-statistic	2.236481	Durbin-Watson stat	2.021418
Prob(F-statistic)	0.107176	Wald F-statistic	3.719927
Prob(Wald F-statistic)	0.024451		

Table 19. Final regression for CPI against 20-year rates

Dependent Variable: _30YR
Method: Least Squares
Date: 05/07/15 Time: 16:43
Sample: 4/01/2009 3/30/2015
Included observations: 1564
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002462	0.002592	0.949797	0.3424
EXPECTED_INFLATION	-0.000904	0.000816	-1.107742	0.2681
CPI_SURPISE	-0.001819	0.000789	-2.306400	0.0212

R-squared	0.002564	Mean dependent var	-0.000213
Adjusted R-squared	0.001286	S.D. dependent var	0.015895
S.E. of regression	0.015885	Akaike info criterion	-5.444962
Sum squared resid	0.393894	Schwarz criterion	-5.434691
Log likelihood	4260.961	Hannan-Quinn criter.	-5.441144
F-statistic	2.006450	Durbin-Watson stat	2.006305
Prob(F-statistic)	0.134812	Wald F-statistic	3.433239
Prob(Wald F-statistic)	0.032526		

Table 20. Final regression for CPI against 30-year rates

Dependent Variable: _5YR
Method: Least Squares
Date: 05/07/15 Time: 17:35
Sample: 4/01/2009 3/30/2015
Included observations: 1564
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009703	0.006060	1.601011	0.1096
EXPECTED_INFLATION	-0.003122	0.001959	-1.593890	0.1112
PPI_SURPRISE	0.003434	0.001667	2.060111	0.0396

R-squared	0.004747	Mean dependent var	-0.000108
Adjusted R-squared	0.003472	S.D. dependent var	0.036364
S.E. of regression	0.036301	Akaike info criterion	-3.792026
Sum squared resid	2.057028	Schwarz criterion	-3.781754
Log likelihood	2968.365	Hannan-Quinn criter.	-3.788208
F-statistic	3.722783	Durbin-Watson stat	2.053433
Prob(F-statistic)	0.024381	Wald F-statistic	3.316690
Prob(Wald F-statistic)	0.036529		

Table 21. Final regression for PPI against 5-year rates

Dependent Variable: _10YR
Method: Least Squares
Date: 05/07/15 Time: 17:40
Sample: 4/01/2009 3/30/2015
Included observations: 1564
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005582	0.003574	1.561594	0.1186
EXPECTED_INFLATION	-0.001845	0.001133	-1.628122	0.1037
PPI_SURPRISE	0.001864	0.001055	1.767581	0.0773

R-squared	0.003918	Mean dependent var	-0.000207
Adjusted R-squared	0.002642	S.D. dependent var	0.022210
S.E. of regression	0.022181	Akaike info criterion	-4.777250
Sum squared resid	0.768004	Schwarz criterion	-4.766978
Log likelihood	3738.809	Hannan-Quinn criter.	-4.773431
F-statistic	3.070222	Durbin-Watson stat	2.007768
Prob(F-statistic)	0.046691	Wald F-statistic	2.782438
Prob(Wald F-statistic)	0.062194		

Table 22. Final regression for PPI against 10-year rates

Pairwise Granger Causality Tests
Date: 05/18/15 Time: 21:40
Sample: 1 72
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
5Y does not Granger Cause CPI	70	3.61446	0.0616
CPI does not Granger Cause 5Y		0.19387	0.6611

Table 23. Granger causality test between CPI & 5-year interest rates

Pairwise Granger Causality Tests
Date: 05/18/15 Time: 21:37
Sample: 1 72
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
CPI does not Granger Cause 10Y	70	0.07958	0.7787
10Y does not Granger Cause CPI		3.75821	0.0568

Table 24. Granger causality test between CPI & 10-year rates

Pairwise Granger Causality Tests
Date: 05/18/15 Time: 21:42
Sample: 1 72
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
20Y does not Granger Cause CPI	70	3.28636	0.0743
CPI does not Granger Cause 20Y		0.31963	0.5737

Table 25. Granger causality test between CPI & 20-year rates

Pairwise Granger Causality Tests
Date: 05/18/15 Time: 21:52
Sample: 1 71
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
30Y does not Granger Cause CPI	70	4.18371	0.0447
CPI does not Granger Cause 30Y		0.44708	0.5060

Table 26. Granger causality test between CPI & 30-year rates

Pairwise Granger Causality Tests
Date: 05/18/15 Time: 21:54
Sample: 1 71
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
_5Y does not Granger Cause PPI	70	0.63447	0.4285
PPI does not Granger Cause _5Y		1.63188	0.2059

Table 27. Granger causality test between PPI & 5-year rates

Pairwise Granger Causality Tests
Date: 05/18/15 Time: 21:55
Sample: 1 71
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
_10Y does not Granger Cause PPI	70	1.31171	0.2562
PPI does not Granger Cause _10Y		1.25189	0.2672

Table 28. Granger causality test between PPI & 10-year rates