The effects of monetary policy announcements on long-term interest rates

Whether monetary policy announcements affect interest rates is an important and an in the recent literature often debated topic. It seems generally accepted that an increase in the federal funds target rate affects the market interest rate immediately. However, no research has ever proven this theory to be correct. This research tries to identify this relation by showing that a long-term relation exists between the long-term interest rate and two parameters, namely a measure of 'normal' news and a measure of monetary policy news. The equation is estimated by using an OLS regression and the Error Correction Model. The Error Correction Model shows more significant results than the regression does, in which several variables are not significant. The conclusion is that the interest rate reacts significantly different to a monetary policy announcement than it does to other news announcement. The sign of this coefficient, though, remains to be doubtful.

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1. Introduction

Whether monetary policy announcements affect interest rates is an important and an in the recent literature often debated topic. It seems generally accepted that an increase in the federal funds target rate affects the market interest rate immediately. However, no research has ever proven this theory to be correct.

Policy makers find interest rate changes important since these rates are the main instruments for central banks to pursue monetary policy and to create price stability. Price stability, and thus low inflation, creates sustainable long-term growth (Bofinger, Reischle, & Schächter, 2001). Agents are affected by the market interest rates and the way they affect the real economy.

In this paper I will examine whether there is an effect of monetary policy announcements on long-term interest rates in the United States over the period 2000-2011. The Federal funds rate will be tracked, as announced on a regular basis by the Federal Reserve. This method has previously been used by Kuttner (2001) and Thornton (2009), but in this paper I will introduce an additional variable and another method in an attempt to find empirical proof for such a relationship.

This approach is innovative in different ways. First, it takes into account the time period that includes the sub-prime mortgage crisis, in which markets were more volatile and uncertainty was significant higher than under 'normal' circumstances. Theoretically, an economy with more uncertainty finds it harder to set expectations and monetary policy announcements should be less anticipated in advance. This implies that a monetary policy announcement should have a bigger effect on interest rates. In order to verify this hypothesis about uncertainty, another timespan is chosen in which the crisis is excluded. If the data show significant effects under this more certain economic conditions, this hypothesis seems to be true. Second, this paper also takes into account the public debate about the rising debt levels in the USA. Public debt is incorporated in this research to examine whether this variable had significant effects on the long-term market interest rates. The third novel feature of this study is its use of a different econometric model, which can determine the short-term deviations from the long-run equilibrium (Miller, 1991). This model is the Error Correction Model (ECM). By adding these three features to existing models an attempt will be made to present a more refined model of the relationship and the direction of this relationship between monetary policy announcements and long-term market interest rates in the United States. The conclusion can be drawn that a change in the target rate has no significant effects on the long-term interest rate. The change in the future rate, however, has a significant effect. This finding can be explained with stating that monetary policy news affects long-term interest rates different than other news does.

The structure of the paper is as follows. Section 2 will present the theoretical framework behind the relevance of long-term interest rates in which the effects on the real economy are outlined. Section 3 will present a theoretical framework on monetary policy, which presents both the IS-LM model and the IS-IRT model. By using these models, this section will elaborate further on the difference between monetary policy targeting and interest rate targeting. Section 4 will describe the determinants of long-term interest rates, distinguishing between the transmission mechanism and the other determinants. Section 5 will briefly discuss the literature regarding announcement theory after which the empirical part of this research will start in section 6, which will describe the methodology and data. Section 7 presents results after which conclusions are drawn in section 8.

2. Relevance of long-term interest rates

Interest rates are important because they affect the real economy through the national income identity. This identity is shown in the following equation:

$$y = c(y,r) + I(y,r) + g \qquad (1)$$

with y being output (which is interchangeably called income), c being consumption, I being investment and g being government spending. The assumption is made in the literature that both consumption and investment depend positively on output, but negatively on the real interest rate r, while government spending is exogenous. The assumption about consumption and investment can be underpinned by theory. First I will elaborate on the consumption effects and subsequently there will be an explanation on investment effects.

The effect of interest rates on consumption decisions can be described following a simple two-period textbook model as proposed by Cromb and Fernandez-Corugedo (2004). The first period is the current period, while the second period is one period later. The current period is period 0 and the latter one is period 1. The theoretical framework starts by looking at the impact of interest rates changes when all income is earned in the first period, so the current period 0. This implies that $y_0 \neq 0$ and $y_1 = 0$ - income in the second period, period being zero. The consumer has the following budget constraint for the two periods. Consumption over the two periods (c_0 and c_1) is equal to income in period 0 (y_0), since income in period 1 is zero:

$$(1+r)c_0 + c_1 = (1+r)y_0 \qquad (2)$$

The budget constraint has a slope that is equal to $-(1+r)$ with the negative sign implying that it is a downward sloping budget constraint, depending on the interest rate (r). An increase in the interest rate will cause the budget constraint to become steeper, as seen in figure 1a, where BC1 is the 'normal' budget constraint and BC2 is the budget constraint after an increase in the interest rate. The indifference curves indicate the preferences of the agent and shows what the optimal distribution of consumption is for this agent. Since income is only earned in period 0, the interest rate increase has no effect on the intercept change in current consumption, but it does affect the intercept in second period consumption. Due to the increased incentive to save with this higher interest rate, current consumption will reduce and futures consumption will increase, since future consumption is relatively cheap. This is the substitution effect, since current relatively expensive consumption is substituted for future relatively cheaper consumption. The income effect is the second effect that is obtained from an increase in interest rates. This effect implies that agents have more room to spend on all goods due to the higher return on savings and implies that current consumption will increase. The effects work counteractive, so the net effect will depend on the elasticity of substitution. The starting point in figure 1a is point I with the interest rate r. The initial indifference curve is drawn on the BC2 constraint with help of the dotted line, which is parallel to BC2. From this the optimal level of consumption after the interest rate increase can be seen at point III. A small amount of current consumption is given up in order to obtain more future consumption. If the elasticity of substitution is low, the agent will prefer to consume an equal amount in both periods and thus consumption will be higher in period 0, than it is stated here. The opposite holds true when elasticity is high. The income effect implies the price of future consumption with a changed interest rate. Due to this effect, less consumption has to be given up at the current moment, to achieve a given level of consumption in the future. This effect is always positive, even when agents are in debt since assets and/or liabilities have no influence on the price of future consumption (Cromb & Fernandez-Corugedo, 2004).

Unfortunately, this simple model does not reflect reality, so more periods are added which will affect the budget constraint. Now assume that income is earned in two periods, so it is divided differently as seen in figure 1b. In this case $y_0 \neq 0$ and $y_1 \neq 0$, so income is received in both periods. The budget constraint is given by:

$$(1+r)c_0 + c_1 = (1+r)y_0 + y_1 \quad (3)$$

The slope of the budget constraint remains $-(1+r)$, but higher interest rates can rotate the slope which opens up the possibility to increase consumption in period 0 and 1. This is shown in figure 1b where BC1 is the budget constraint in the initial period and BC2 shows the constraint after an interest rate increase. As in the one period income model, there is still the possibility to increase consumption in both periods, but only on the terms that there is little current consumption. The difference with the one period income is that in this model a third effect will be added to the income and substitution effect, namely the wealth effect. This effect works in opposite direction of the two other effects, since the second period income has a lower current value of future income. This is due to the fact that:

$$Present\ value\ of\ income = y_0 + \frac{y_1}{1+r} \quad (4)$$

This equation states that consumption depends on the present value of current income and future income, with the current value of future income being discounted by the higher interest rate (Mankiw, 2010). If the wealth effect is large enough, it will offset the income effect and an increase in the interest rate will have a negative impact on consumption. The more income is concentrated to the future, while consumption is concentrated to the current period, the bigger the wealth effect and thus the more negative influence an increase in the interest rate will have on the consumption level. In figure 1b this is seen in the shift from point I with the initial low interest rate, to point III where the interest rate has increased. The dotted line is again parallel to BC2 to set the optimal consumption level. Consumption with a higher interest rate falls back to point III in this figure (Cromb & Fernandez-Corugedo, 2004).

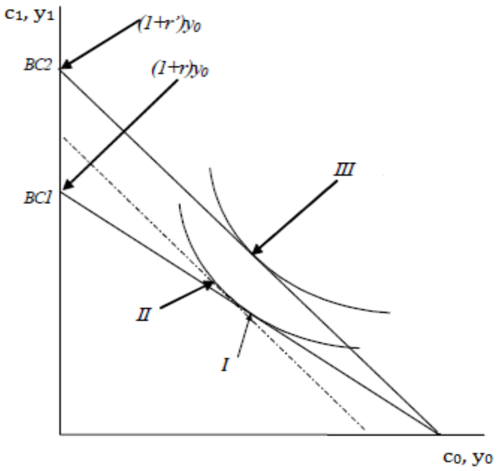


Figure 1a: income only in 0

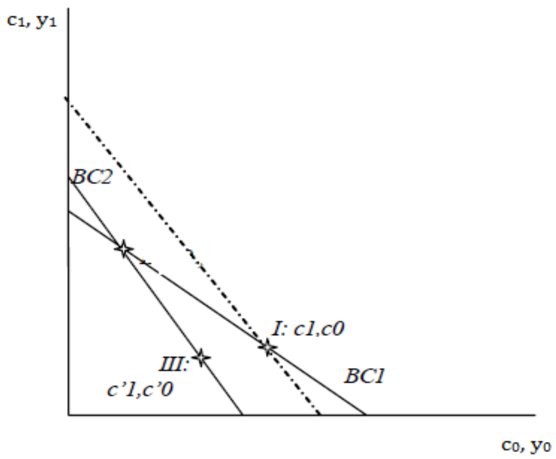


Figure 1b: income in both period 0 and 1

Source: (Cromb & Fernandez-Corugedo, 2004)

After having identified the effects of short-term interest rate increases in one- and two period models, Cromb and Fernandez-Corugedo (2004) show the effects of an interest rate increase on a multiperiod model. The first assumption the authors make is that income is just consumed each period. If the interest rate increases the current value of future income would be reduced (as shown in equation 4), but the rate of return on savings would rise proportionally with the interest rate increase. The proportionate rise in the rate of return implies consumption can remain equal in each period and the wealth- and income effects will cancel each other out. The substitution effect is still present and this effect has a negative impact on consumption giving a consumer with a fixed income of Y will then have the following consumption function:

$$C = (r - g_c)W = \left[r - \frac{(r-\delta)}{\theta}\right]\left(\frac{Y}{r}\right) = Y - \frac{Y}{\theta} - \frac{\delta Y}{r\theta} \tag{5}$$

Where consumption depends on the interest rate, on consumption growth (g_c) and on wealth (W). The consumption growth component depends on the interest rate, the coefficient of risk aversion (θ) and the subjective rate of time preference (δ). From this equation it is shown that there is always a negative effect of interest rate increases on consumption and the size of this negative impact depends on the elasticity of substitution (Cromb & Fernandez-Corugedo, 2004).

Cromb and Fernandez-Gorugedo (2004) use this multi-period framework to look at the effect of both expected future interest rates and current interest rates on consumption. The expected future interest rates in this research are the equivalent of long-term interest rates, since agents have perfect information in this model. The current interest rates are the equivalent of short-term interest rates. The authors make a distinction between a persistent interest rate increase and a temporal interest rate increase. They show that a more persistent increase in interest rates leads to a bigger impact of this interest rate increase on consumption. The logarithmic model that the authors found to prove this is:

$$\ln c_0 \approx \ln y_0 + [\sum_{j=1}^{n-1}\left(\frac{n-j}{n}\right)(g_y(j) - g_c(j))] \tag{6}$$

in which g_y is income growth and g_c is consumption growth. The number n displays the amount of periods in the model. The larger the time period that the interest rate increase persists ($n - j$ is larger), the greater the effect of the interest rate increase is. The authors found this formula to be reliable for short time horizons, but the larger the researched period became (the larger n), the less reliable this formula became. They interpret this finding as indicating that the impact of higher interest rates is roughly linear to the duration of this increase (Cromb & Fernandez-Corugedo, 2004). The drawback that the authors find in this model is that it is very simple and that it assumes perfect information about future interest rates. In reality, there is a lot of uncertainty these rates, which will affect the importance of the long-term interest rates described here (Cromb & Fernandez-Corugedo, 2004).

Consumption spending, as stated above, provides utility at the present, while investment provides a higher output in the future. Investments can be categorized in one of the three types of investment spending, namely residential investment, inventory investment and business fixed investment. The analysis of the effects of interest rate increases on residential investments and inventory investments are pretty straight forward.

Residential investment incorporates all new housing investment, which is both for own use as not for own use. The supply of houses is assumed to be sticky, so the current supply cannot be adjusted to current demand. The demand curve for houses is downward sloping, which implies that a high housing prices relative to the price level ($\frac{P_H}{P}$) will lead to a lower demand for houses, which leads to lower supply of houses in the future. An important determinant of the price of housing is the real interest rate, since the real interest rate is reflected in the mortgage costs. Higher real interest rates will lead to higher mortgages and thus lower demand. Lower housing demand will lead to lower investment (Mankiw, 2010).

Inventory investment is, as the name suggests, the investment in inventory that companies hold. A model that fits this type of investment is the very simple accelerator model which says that companies hold inventories in a linear equation relative to output ($N = \beta Y$). The investment in inventory is the change in inventory stock ($I = \Delta N = \beta \Delta Y$). The real interest rate reflects the opportunity cost of holding large amounts of inventory since they could have earned when it was not used in inventory. A higher interest rate will thus increase the opportunity cost of holding inventory, which will trigger a reduction in inventory stock (so lower or no investment) (Mankiw, 2010).

Business fixed investment is the most important source of investments and includes all the investments that are used for future production. As a consequence, the capital from this spending will be used for some time, which runs counter to inventory investment. This type of investment will be either used or sold pretty quickly. Mankiw (2010) shows that business fixed investment can be modeled by the neoclassical model of investment, in which a distinction is made between a production department of a firm (or a production firm) and the rental department of a firm (or a rental firm). Rental departments undertake the investments necessary in the economy, while production departments produce goods and services while renting capital from the rental department. The production department must decide on how much capital to rent for the necessary production. The production department rents capital from the rental department at rate R and sells the output produced using this capital at a price P. The marginal product of capital (the benefit of a unit of extra capital, which is abbreviated to MPK) declines when output rises, so it is a downward sloping function. The reasoning behind this is that the more capital a firm has, the less output changes by adding one extra unit. The MPK can be approximated by using the Cobb-Douglas function:

$$Y = AK^{\alpha}L^{1-\alpha} \tag{7}$$

where Y stands for output, K stands for capital and L stands for labour. A measures the level of technology and α measures the share of output capital, in which $0 \leq \alpha \leq 1$. The Cobb-Douglas function is equal to the MPK.

The cost of capital is identified by the rental department. Rental departments borrow to buy a unit of capital that they rent further, so the cost of capital for this rental firm is:

$$Cost\ of\ capital = P_K\left(i - \frac{\Delta P_K}{P_K} + \delta\right) \tag{8}$$

In which P_K is the purchase price of one unit capital and i is the nominal interest rate. Depreciation is measured by δ. When accounting for inflation, the real cost of capital is depicted by:

$$Real\ cost\ of\ capital = \left(\frac{P_K}{P}\right)(r+\delta) \tag{9}$$

and thus this real cost of capital depends on the real interest rate. A rental department will decide to increase or decrease the capital by looking at the profit rate, which is the MPK subtracted by the real cost of capital. An investment will only be pursued when the profit is positive, so the investment function will depend on this profit rate. Total investment spending is shown by net investment and the replacement rate of depreciated capital (δK):

$$I = I_n\left[MPK - \left(\frac{P_K}{P}\right)(r+\delta)\right] + \delta K \tag{10}$$

In which $I_n[\,]$ is the function that shows how net investment responds to the incentive to invest. This formula immediately shows the dependence of investment spending on the interest rate. A decrease in the real interest rate r will lower the cost of capital. This lower cost of capital raises the profit rate from capital investment and thus it increases the incentive to invest more. An increase in the real interest rate will have the inverse effect and thus lead to a decrease in investment spending (Mankiw 2010). Theory implies that the interest rate mentioned here, is the long-term interest rate. When the marginal cost of capital increases, there are opportunities from forecasting this rate, since spending can be spread more optimally over time. This will minimize costs which makes that long-term interest rates are more important in this theory than short-term rates (Lawrence & Siow, 1985).

3. Monetary policy

The short-term interest rate set by pursued monetary policy will affect the long-term interest rate, which in turn will affect the real economy in consumption and investment decisions which is shown in the former section. The next important relation that has to be outlined is what effect pursued monetary policy has on the long-term interest rate. The goal of central banks is to set a monetary policy framework in such a way that it can achieve stable and low inflation, but still has the possibility to react to shocks (Cecchetti, 2003). In order to achieve this, a central bank can choose between two operating targets, namely the money supply or the interest rate. The choice of operating target depends primarily on the policy objective and the structure of the economy.

The macroeconomic IS-LM model shows monetary transmission by targeting the money supply, after which the interest rate is affected as shown by (Bofinger, Reischle, & Schächter, 2001). The model represents two markets with two different equations, namely the goods market (IS) and the money market (LM). Only a closed economy is accounted for to keep the analysis simple. The IS equation is derived from the national income identity (which was outlined earlier):

$$y = c(y,r) + I(y,r) + g \tag{11}$$

The real interest rate is used here, since I assume that inflation is zero. The IS curve gives the equilibrium combinations of y and r in the goods market and is implicitly written as follows:

$$IS(y, r, g) = 0 \quad (12)$$

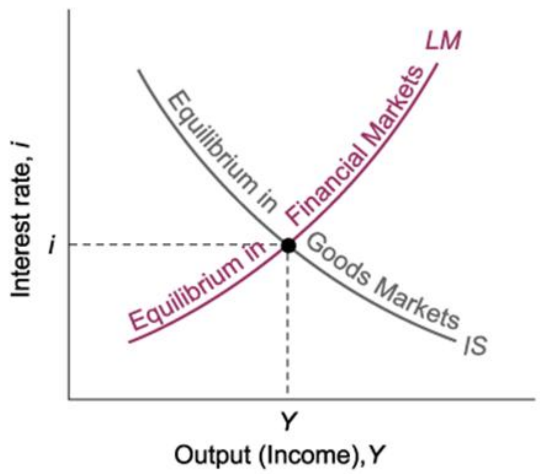
The LM equation is derived from the money market equation and states that the price level and the money stock are given:

$$M = PL(y, r) \quad (13)$$

which shows the demand function for nominal money balances. These money balances depend positively on output and negatively on the interest rate. M is the nominal money supply, which is assumed to be given. From this the LM function can be derived that gives the equilibrium combinations of y and R as (Bofinger, Reischle, & Schächter, 2001):

$$LM(y, R, P, M) = 0 \quad (14)$$

Figure 2a shows the relation between the IS and the LM curve with output and the interest rate on depicted on the axes, as identified by Blanchard (2005). The IS curve slopes downward because there is an inverse relation between output and interest rate, as seen earlier. The LM curve is upward sloping and thus implies that there is a positive relation between the level of output and the interest rate in the money market. Figure 2b shows the effect of a monetary expansion on the LM curve. With an increase in the money supply and a fixed price level, the real money stock $\frac{M}{P}$ will increase. This increase will lead to higher output Y' and a lower interest rate i'.



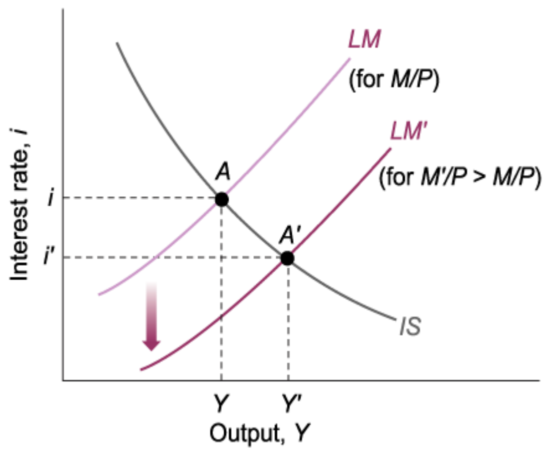


Figure 2a: IS-LM (Blanchard, 2005)

Figure 2b: shifting LM curve (Blanchard, 2005)

In the IS-LM model, the money supply is set exogenously, with the interest rate depending on this level of money supply. In reality, most central banks in developed countries control the interest rate. The IS-IRT model is an alternative to the IS-LM model which takes into account the central bank setting interest rates exogenously and assuming that prices are fixed. This model is based on the Taylor rule (Handa, 2008), which will be specified in the remainder of this paper. The IS-IRT model assumes that the central bank holds the interest rate constant over time, just like the central bank held the money supply constant in the IS-LM model. The assumption made in this model is that the central bank sets the real interest rate fixed to the target rate, so $r = r_0^T$.

When this is plotted the target real interest rate is a horizontal line (plotted in figure 3a). Also another assumption can be made in this model, viz. that a simple feedback rule is used. The following equation will arise:

$$r = r_0 + \beta_y(y_t - y^f) + \gamma_p(P_t - P^T) \quad (15)$$

with β_y,γ_p> 0, and $y_t - y^f$ being the difference between actual output and output at full employment level. This can be identified as the output gap, which for simplicity is written as y_t^d in the remainder of this paper. A positive relation exists between the interest rate and the output gap in equation 15, so the IRT curve is upward sloping, as displayed in figure 3b. An increase in P would shift the entire curve up, indicating that there is a higher interest rate at any given level of output (Handa, 2008).

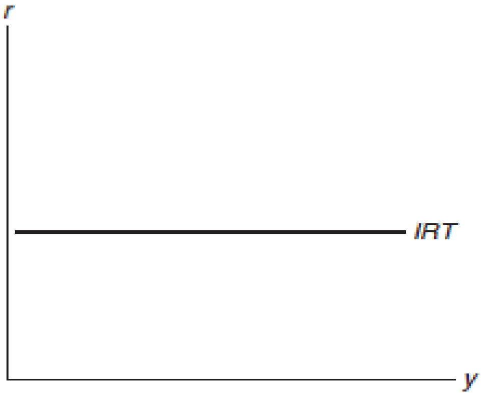


Figure 3a: the horizontal IRT curve (Handa, 2008)

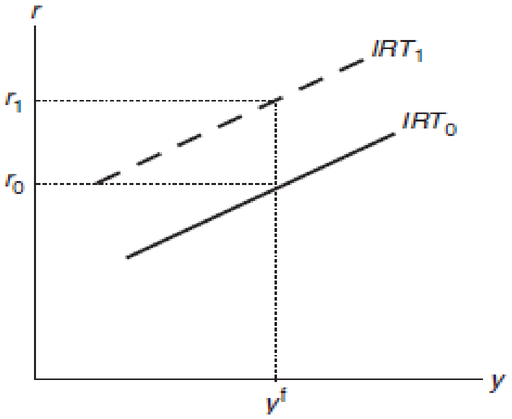


Figure 3b: Upward sloping IRT curve (Handa, 2008)

Monetary targeting happened especially in the late 1970s and early 1980s in the United States of America, Canada and the United Kingdom. This form of monetary targeting was assumed to achieve a steady relationship between this target and aggregate demand. It was also assumed that the lag between these two variables would be short and easy to forecast, which made it a good target. This assumption was proven to be wrong when an unstable relation occurred, partly due to financial innovations and changes in the technology of payments in the late 1980s. Monetary targeting has therefore been abandoned in the three countries from the 1990s onward and interest rate targeting has become the main national targeting policy. The advantage of the interest rate as a target is that interest rates are reliable and appropriate indicators for necessary action, which is mainly accountable to the fact that interest rates affect spending and that they serve as main indicators for economic performance. The rate that is targeted in most developed countries is the overnight loan rate, since the overnight market holds the excess reserves of commercial banks and thus reflects supply and demand conditions for reserves. By targeting this rate, the central bank can influence commercial demand and supply for reserves which will influence longer-term interest rates and thus the real economy. The fact that the interest rate is the main targeting instrument does not mean that the central bank forfeits money supply adjustments completely. The necessary levels of money supply are needed to achieve the desired interest rate levels. When the money supply is completely abandoned, the interest rates would diverge from this desired level so interest rate targeting must be accompanied by the correct level of money supply in order to achieve its goal (Handa, 2008).

The choice for either inflation targeting or interest rate targeting can be explained mathematically. To do so, one first needs to rewrite the variables in the IS-LM equation into deviations from their own trend value. This means that the constants in the IS-LM curve are deleted. The following equations are then identified (Handa, 2008):

$$IS: y_t^d = -\propto_r r_t + \mu_t \tag{16}$$

$$LM: \left(\frac{M}{P}\right)_t = -m_R r_t + m_y y_t^d + \eta_t \tag{17}$$

The two last parameters in the equations are stochastic disturbances. μ_t is the stochastic disturbance of expenditures on commodities, while η_t is the stochastic disturbance in the money market. These parameters have a zero mean and are uncorrelated. $\propto_r$ in the IS curve displays the sensitivity of the interest rate on the goods market. The right hand side of the LM curve displays the money demand in real terms, assuming that inflation is constant and thus inflation expectations are zero. The other variables are already explained in the former part.

The central bank aims to reduce the deviation from the trend, which implies that $y^d = 0$ when shocks do not exist. The nonexistence of a shock would also imply that the disturbances are zero and thus μ=η=0. A shock can only occur when either one of the disturbance terms is significantly different from zero. The following function needs to be reduced:

$$minimize\ E\left(y_t^d\right)^2 \tag{18}$$

When money targeting is the used policy framework, one can solve this function for by solving:

$$y^d = \frac{\alpha_r\left({}^M/_P\right) + m_R\mu - \alpha_r\eta}{\alpha_r m_y + m_R} \tag{19}$$

Targeting the money supply such that $E\left(y^d\right) = 0$ assumes that $\left({}^M/_P\right) = 0$ and thus the equation becomes:

$$y^d = \frac{m_R\mu - \alpha_r\eta}{\alpha_r m_y + m_R} \tag{20}$$

The variance of this function can be easily written as:

$$E^m\left(y^d\right)^2 = \frac{{m_R}^2\sigma\mu^2 - {\alpha_r}^2\sigma\eta^2}{(\alpha_r m_y + m_R)^2} \tag{21}$$

in which E^m implies that this function shows the variance of monetary base targeting.
When interest rate targeting is the instrument used, the LM curve will be zero and thus the IS curve is the only curve that will be shown here. The variance in this case becomes:

$$E^r\left(y^d\right)^2 = \sigma\mu^2 \tag{22}$$

E^r in this function implies that the equation shows the variance of interest rate targeting. The targeting method with the smallest expected variance is the most preferred targeting method, so if:

$$\frac{m_R{}^2\sigma\mu^2 - \alpha_r{}^2\sigma\eta^2}{(\alpha_r m_y + m_R)^2} < \sigma\mu^2 \tag{23}$$

then monetary base targeting is a better suited policy than interest rate targeting. This is mostly the case when there are only commodity market shocks and no money market shocks. If the inverse is the case, so money shocks and no commodity market shocks, than the interest rate is the preferred monetary target. As already mentioned, most developed countries use interest rate targeting as policy (Handa, 2008).

4. Additional Determinants of long-term interest rates

The IS-LM and IS-IRT model, as explained earlier, are simple models that display the effect of monetary policy on output and interest rates. These models do have a few drawbacks, such as:

- They only take into account one interest rate, with no clear explanation which interest rate this is;
- They can only identify two financial assets, namely money and bonds. More financial assets could enhance the models and give a deeper explanation of the macroeconomic movements;
- Both models only describe the short-term changes, since they assume that capital stock, technology and labour force are constant. Improvements could be made by accounting for the long-run (Handa, 2008).

In order to deepen the analysis of monetary policy changes, three determinants will be introduced. These models are the Fisher equation, the Term Structure and the Taylor Rule. These models will look at interest rate setting, long-term interest rates and the distinction between nominal and real rates.

1. Transmission

In the former part of this paper I identified how monetary policy is pursued through interest rate targeting, meaning that the nominal interest rate is set by the central bank. The rule that has been formulated to identify the optimal target rate by central banks is the Taylor Rule. This rule was developed by John Taylor (1993) and states that central banks set the interest rates to two important determinants, namely the divergence of the inflation rate from the target rate and the divergence from the targeted long-run output (Gerdesmeiers, Mongelli, & Roffia, 2007). When the output gap is positive (and thus output is above the trend), or inflation is above the target rate, the central bank increases the nominal interest rate. If there is a negative output gap, or inflation is below the target rate, the central bank decreases the nominal interest rate. The Taylor rule is not a theoretically derived model, but it has been established from empirical data from a study of actual monetary policy of the Federal Reserve in the period 1987-1992 (Taylor, 1993). The author specified the coefficients, but a general form of the Taylor rule is the following (Bofinger, Reischle, & Schächter, 2001):

$$i_t = \pi^* + \alpha\,(\pi_t - \pi^*) + \beta\,(\frac{Y_t - Y^*}{Y^*}) \tag{24}$$

Specifically, this rule states that the nominal long-term interest rate (i_t) has to be set equal to an inflation target (π^*) and to the term that shows the deviation from the inflation target and the output gap. The two coefficients α and β show the weights that are given to the output gap and the deviation of the inflation rate from its target. The Taylor rule is an empirically derived model and it shows a very good performance in empirical research, but a major drawback is the simplistic assumptions that all relevant information that is necessary to pursue monetary policy, is captured in the current inflation rate and the output gap. (Gerdesmeiers, Mongelli, & Roffia, 2007).

The Taylor rule defines the optimal long-term interest rate in the economy, but long-term rates are not set by the central banks. The short-term rate is targeted, so there must be a relation between these two rates. The term structure of interest rates is the main relation that explains the formation of the long-term interest rate. Expectations theory is the most important theoretical framework to predict future short-term interest rates, which together set the long-term interest rate. The expectations hypothesis implies that there is an equilibrium (steady-state) relationship between interest rates of different maturities, so short-term rates cannot drift away from long-term rates. This theory was initiated by Irving Fisher (1930) but the main developments can be attributed to Lutz (1941) and Hicks (1946). Arbitrage is central to this theory, stating that short-term and long-term assets are perfect substitutes. This indicates that they only differ in maturity. The long-term interest rate is shown to be a weighted average of the current short-term interest rate, the expected future short-term rates and a constant risk premium. This risk premium is set to zero in the pure expectations hypothesis, but this assumption in the pure expectations hypothesis is too strong in reality. The basic assumption of the expectations hypothesis theory is that financial investments are homogeneous and thus different prices and risks are ignored (Bofinger, Reischle, & Schächter, 2001). This relation can be stated as follows:

$$i_{long} = \sqrt[n]{(1 + i_{short}^{t})(1 + i_{short}^{e_{t+1}})(1 + i_{short}^{e_{t+2}}) \ldots . (1 + i_{short}^{e_{t+n}})} - 1 + risk\ premium \tag{25}$$

Since the only short-term interest rate known is the interest rate at time t, expectations on the other rates have to be formed. This means that there is still a price risk and that there can be no true arbitrage relationship (Bofinger, Reischle, & Schächter, 2001).

This expectations hypothesis is also the main theoretical framework behind the theory regarding the impact of monetary policy announcements on interest rates. In order to outline this theory, the first assumption made is that long-run characteristics will be constant over time. The second assumption is that all agents have perfect information. These two assumptions lead to a vanishing effect of monetary policy announcements in the long-run. The idea behind this reasoning is that expectations about short-term rates that are far enough in the future, will be relatively sure since agents know what is going to happen (have perfect information) and thus this information is already priced in the interest rates. This assumption is also the theory's main drawback. When this assumption is abandoned and inflation expectations are assumed to adjust to announcements, there is a significant effect of monetary policy announcements on long-term interest rates which is attributable to the revision of expectations (Gürkaynak, Sack, & Swanson, 2005).

As shown earlier, long-term interest rates affect the real economy. The relation between the short-term and the long-term interest rate, though, can give signals about the state of the economy. This relation is seen in the yield curve. The slope of the yield curve (X_t) is defined as the difference in period t between the yield of the long-term domestic bond (i_t^l) and the short-term bond(i_t^s).

A longer yield to maturity gives a higher risk premium and thus an upward sloping yield curve.

$$X_t = i_t^l - i_t^s \quad (26)$$

The upward sloping yield curve shows that the long-term interest rate is higher than the short-term rate and this is being regarded as the “normal” yield curve. A downward sloping (inversed) yield curve is explained by the fact that the short-term interest rates are higher than the long-term interest rates (Mishkin, 2007). It is shown in Bofinger et al. (2001) that an inverted yield curve can signal a recession, with the rational for this being that the slope of the yield curve is seen as a monetary policy indicator. Monetary tightening results in short-term interest rates that are high relative to long-term rates, so these will affect the economy. Three variables that shape the yield curve are: the real interest rate, inflation and the risk premium (Mehl, 2009) for which the relation can be explained by the Fisher equation. This theory was developed by Irving Fisher (1930) and states that nominal interest rates move fully in line with expected inflation. This implies that, all other things being equal, the real interest rate should be constant to the inflation rate.

$$i_t = r_t + \pi_t^e \quad (27)$$

When perfect foresight is assumed, the Fisher equation shows that inflation tendencies (π_t^e) that are triggered by changes in the money supply will be fully reflected by an increase in the nominal interest rate (i_t). These inflation tendencies will not affect the real interest rate (r_t). As the real interest rate is solely determined by non-monetary factors, a co-movement between the long-term interest rate and the inflation rate is seen (Bofinger, Reischle, & Schächter, 2001).

As has been stated previously in this paper, a change in the target interest rate looks as if it is directly incorporated in the current interest rate. This is incorrect however. An inertia in monetary policy has been identified, which is a lag in the speed of adjustment. The lag is shown by the following equation according to Rudebusch (2002):

$$i_t = (1 - \rho)i_t^* + \rho i_{t-1} \quad (28)$$

where i_t is the current level of interest rate and i_t^* is the target rate. ρ is a parameter that is estimated to be around 0.8 so there is a very slow adjustment of the policy rate to its fundamentals. This slow adjustment can be optimal behaviour for a central bank, explained by the fact that i_{t-1} is likely to be an important state variable and thus the optimal instrument rule would include a response to its value. This means that partial adjustment is the optimal strategy when the private sector has forward looking expectations and there is a credible commitment to such a policy rule. The small expected inertial changes in the interest rate policy can have a large effect on current supply and demand (Rudebusch, 2002).

2. *Other determinants*

In addition to the transmission mechanisms described above, other determinants also affect interest rates, such ase inter alia, budget deficits and their accompanying debts. The effect of budget deficits and debts on interest rates is an often debated topic, especially within the context of the current European crisis. The approach shown here will focus on the effects of government spending on aggregate demand and interest rates and the economy as a whole. There will be no estimation of the effect of debts on resource allocation. The following identity can be applied to the public sector debt in a closed economy, for which the only source of income are taxes:

$$D = G - T + iB = \Delta B + \Delta H \qquad (29)$$

where D is governmental budget deficit, G is government expenditure, T implies taxes and is a source of income, $iB$is the interest payment that is applicable to the outstanding debt, $\Delta B$is the change in bonds in order to finance the budget deficit and ΔH is the change in high powered money, which can be used to finance the budget deficit. Since high powered money has a small share in reality, and to make the equation easier, one can ignore this item. This implies that ΔH= 0 and that deficits are automatically added to government debt. The primary deficit, which is the difference between government expenditure and tax revenues, can be related to GDP in the following manner:

$$x = \frac{G - T}{Y} \qquad (30)$$

This relation (x) can be substituted in an equation showing the change in debt-to-GDP ratio in the following way:

$$\Delta b = b(r - n) + x \qquad (31)$$

in which b is the debt-to-GDP ratio, and n is the real rate of growth. The equation tells that an increase in the debt-to-GDP ratio depends on the primary deficit and on the debt ratio multiplied by the real interest rate minus the real rate of growth. This latter multiple is important, since the key figure is the debt ratio, rather than the debt level (Allsopp & Vines, 2005).

There are various theories about the effect of budget deficits on long-term interest rates. Barro (1974) first outlined the Ricardian Equivalence Hypothesis (REH) stating that deficits do not affect interest rates, but interest rates are only affected by government spending and taxation. This is a very strong hypothesis which has as underlying reasoning that the increase in government borrowing is fully offset by an increase of private market saving. The net effect of debt is cancelled out and there is no effect on interest rates. There is little empirical evidence that supports this strong theory, but the weaker form is seen as a more applicable approach. Standard Keynesian theory, on the other hand, states that government expenditures (or tax cuts) lead to a GDP increase that is a multiple of the initial expenditure. This effect will be especially large when savings rates are low, since the proportion of funds being consumed is high in this case (Ussher, 1998). Stiglitz et al (2006) emphasize the importance of making a distinction between expansionary fiscal policy in a recession and when the economy is in full employment. The authors first define the 'crowding out' effect as increasing government borrowing leading to higher interest rates, which reduces private investments. Both the REH model and the Keynesian theory have a crowding out effect, but government borrowing gives the Keynesian model an extra source through which this crowding-out occurs (Ussher, 1998). There are two sources of crowding out, namely the "real" source and the "financial" source, which both come from an increase in government borrowing relative to taxation (Stiglitz, 2006):

- The "real" crowding out effect states that higher government borrowing will reduce private investment because of aggregate supply constraints.

- The “financial” crowding out effect relates these same reductions in investment after increased government debt to constraints on the financial markets.

The neoclassical school of thought has another theory which attributes the real crowding out effect to a theory of “loanable funds”. This theory states that higher government borrowing increases the demand for loanable funds, which increases the incentive to save. Interest rates will increase and private investments will be lowered (Ussher, 1998).

When the economy is at full employment it indicates that the ‘pie’ is fixed. An increase in government debt must come at expense of another item, so either consumption or investment must be reduced in the economy, which will lead to lower output. When the economy is in a recession and below full employment an increase in government spending can be applied without a decrease in private investment. The crowding out effect implicitly assumes that central banks cannot take actions which would lower interest rates, other than increase the money supply (Stiglitz, 2006). In an open economy the reasoning is somewhat different Assuming that there is not a pure Ricardian effect, an increase in government borrowing will lead to some private saving, but this savings rate is not high enough to offset the government spending. The reduction in national saving will increase interest rates, which leads to a capital inflow. This capital inflow will diminish the initial interest rate increase. The capital inflow, however, increases domestic currency demand which leads to an appreciation of the domestic currency and thus makes exports more expensive. A reduction in exports and an increase in imports are the result. Net exports are lower and the only effect of the government borrowing is an appreciation of the national currency (Lipsey, Courant, & Ragan, 1999).

The common formula to explain the above mentioned crowding out effect is explained by Hubbard (2011) and is shown to be the Cobb Douglas function with the accompanying MPK curve as explained earlier. This MPK would increase if capital (K) would be crowded out by government debt (D). The total return to capital (MPK x K), depending on output, would then equal α in the following formula:

$$\propto = \frac{(MPK \times K)}{Y} \tag{32}$$

with the interest rate is determined by:

$$r = MPK = \propto\times \frac{Y}{K} = \propto\times A \times \frac{L}{K}^{1-\propto} \tag{33}$$

Assuming that government debt completely crowds out capital will give:

$$\frac{\delta K}{\delta D} = -1 \tag{34}$$

If government debt increases, all other things being equal, the interest rate will also increase following the formula:

$$\frac{\delta r}{\delta D} = \frac{\delta r}{\delta K} \times \frac{\delta K}{\delta D} = \alpha \times (1{-}\propto) \times \frac{Y}{K^2} > 0 \tag{35}$$

since ($0<\alpha<1$ and $Y,K>0$)

The implication of this model is that the interest rate is determined by the level of capital stock, which is determined by the level of government debt. The interest rate change is affected by the budget deficit, which is equal to the change in government debt. The effects on interest rates are ambiguous, since studies use debts and deficits interchangeably (Hubbard, 2011).

Another theory that is often followed, and is a highly important matter for the IMF, is the Loss of Confidence Theory. In this view there is a negative effect of government borrowing on interest rates, since investors lose confidence when seeing rising deficits and debts. There will be less private investment and only a resolute reduction of government borrowing will be able to restore confidence. Little empirical research has been done on this subject (Stiglitz, 2006).

All theoretical models above show that there is still not one model that explains the effects of government debt on long-term interest rates. Since the basic theories are outlined above, it is up to the empirical results to provide the correct effect on this dataset.

Now the theory behind interest rates is fully covered, I will provide a short overview of the literature on the subject of monetary policy announcements. This literature will help to identify the proper methodology on this subject.

5. Literature on monetary policy announcements

The economic literature on the effect of policy announcements on interest rates is vast. In an early study in the debate on announcements, Engel and Frankel (1984) showed that the nominal interest rates rose when the Fed announced a nominal money supply that was greater than expected. This is explained by the rise in real interest rates as anticipating the FED's offsetting policy action (so a contraction in the money supply) (Engel & Frankel, 1984). A few years later, Cook and Hahn (1989) were the first to look specifically at the Federal Funds rate as the main policy rate of the Fed. They estimated the response of daily Treasury yields to changes in this target rate and found that these changes in the target rate caused large movements in the short-term rates but small movements in long-term rates (Cook & Hahn, 1989). Kuttner (2001), elaborating on this research, concluded that Cook and Hahn (1989) presented overestimated effects. The author estimated the impact of monetary policy actions on different yields, using the federal funds futures rate to identify a surprise component while looking at the impact of a change in monetary policy. He concluded that the actual response of interest rates is small relative to anticipated changes in target rates, but significantly large to unanticipated changes in the target rates (Kenneth N, 2001). Kearny (2001) showed that unanticipated monetary policy and employment announcements have a positive effect on the T-Bill rate, while the magnitude of the response depends on the expectations for the policymakers' response to the news (Adrienne A., 2001). Gürkaynak et al. (2005) showed that the effects of both monetary policy and macroeconomic news announcements are neither in line with theory nor with earlier research, since their results showed a significant interest rate change. They explain their findings along two different lines. The first explanation is that the earlier research they examined does not take into account future rates, which may explain the difference in outcomes. (The article is not based on Kuttner (2001)). A second explanation as to why actual results were significantly different from theory, elaborated on the fact that long-term determinants are not constant in reality (Gürkaynak, Sack, & Swanson, 2005). Thorton (2009) based his research on Kuttner (2001) but implemented the joint-response bias in the research, stating that: "*The joint-response bias exists because interest rates and market-based monetary policy shock measures respond to all information relevant to interest rates. Hence, in order to identify the effect of surprise monetary policy actions on interest rates, it is necessary to account for the response of interest rates to ambient news*" (Thornton, 2009). The correction for the bias can be made by accounting for all days in the sample and not only the days when policy actions were made. The author shows that by accounting for the bias, the event-study of Kuttner (2001) overestimated the effect on monetary policy shocks consistently (Thornton, 2009).

6. Methodology

In this paper I will examine the effects of monetary policy announcements on long-term interest rates in the US, within the period January 3rd, 2000 until July 27th, 2011. This timeframe is chosen on purpose, since the FOMC announced on December 21, 1999 that they targeted the funds rate. On February 2, 2000 the FOMC specified a precise target and with that all ambiguity about the target level vanished. Ambiguity about this target level should show in the behaviour of the funds rate, so by eliminating this ambiguity, the regression will be a better estimate (Thornton, 2009).

I will base my methods on Thornton (2009) and thus, indirectly on Kuttner (2001) and also on the early findings of Cook and Hahn (1989). The starting point of the study is a simple equation to identify whether a change in the Federal funds target rate has a significant effect on the change in interest rate. The methodology used is the federal funds target rate as suggested by Cook and Hahn (1989). The following equation will be estimated:

$$\Delta i_t = \alpha + \beta \Delta ff_t^*(PE) + \gamma \Delta DEBT + \varepsilon_t \quad (36)$$

where Δi_t is the change in the 5-,7-,10- or 30-year Treasury bond rate, PE is a dummy variable for monetary policy announcements, being one (1) if there was a monetary policy announcement and zero (0) otherwise. The dummy variable will include all days when there was an FOMC meeting, which includes both days when the interest rate has changed and days when there was no change in the target rate. The variable Δff_t^* is the change in the Federal Funds target rate. The dummy variable and the target rate change are multiplied, since every change in the target rate is announced by the FOMC. The variable ΔDEBT is a control variable that takes into account the effects of the change in the level of government debt over the time span. There is no variable on deficits in this model since these are already incorporated in the change in debt in the long-run. This equation will show whether news about monetary policy ($\Delta ff_t^*(PE)$) will affect long-term interest rates. The news included in this model is both expected and unexpected news, which should be seen in the results. The literature has shown that expected news does not affect interest rates, which means that this news component here should not be significantly different from zero (Kenneth N, 2001).

The next step is to make this distinction between expected and unexpected announcements, for which only the unexpected component is used in this research, since expected news is already mentioned to be insignificant. This unexpected component of news can be isolated by using the Federal Funds futures rate. These futures contracts are settled at the end of the given month and the settlement is done based over the average federal funds rate realized in this month. The futures rate is thus a weighted average of the observed funds rate up to the analysed day and the market's expectation of the funds rate over the remainder of the days within the month (Thornton, 2009). The equation that Kuttner (2001) describes to identify the unexpected component of the announcement is the following:

$$\Delta ff_t^{*u} = \frac{m}{m-t}\,(fff_t^0 - fff_{t-1}^0) \tag{37}$$

in which Δff_t^{*u} is the unexpected component of the target rate, $fff_t^0 - fff_{t-1}^0$ is the change in the current- month federal funds future rate and m is the number of days in the month, up to the current time. If there is no news that affects the futures rate, $fff_t^0 - fff_{t-1}^0 = 0$. Only news that is not already incorporated in the futures rate, will show a change. Since this measure cannot be calculated for the first day of the month, Kuttner (2001) replaced the current-month futures rate with the 1-month-ahead futures rate for the last three days of the month. The equation then becomes:

$$\Delta ff_t^{*u} = \ (fff_t^1 - fff_{t-1}^1) \tag{38}$$

Since Poole and Rasche (2000) have used this last equation for the entire dataset and the results were qualitatively the same as the method used by Kuttner (2001), I will use this latter formula for the unexpected component in the futures rate over the entire sample. Thus, the futures rate used will be the one month ahead rate.

The second improvement is that the joint-response bias will be taken into account in this second model, as proposed by Thornton (2009). This is done by looking at the entire sample and using a dummy variable to distinguish between days with FOMC announcements and days when these announcements did not occur. The second model is the following:

$$\Delta i_t = \alpha + \alpha'(PE) + \beta\Delta ff_t^{*u} + \beta'\Delta ff_t^{*u}(PE) + \gamma\Delta DEBT + \varepsilon_t \tag{39}$$

In this equation, the variables are generally the same. A short recap tells us that Δi_t is the change in the 5-,7-,10- or 30-year Treasury bond rate, PE is a dummy variable for monetary policy announcements, Δff_t^{*u} is the change in the Federal funds futures rate, which is implemented to capture the unexpected changes in the futures rate (Thornton, 2009). The variable ΔDEBT is the change in debt. New parameters are both β and β'. The parameter β signals the response of interest rates to news and β' signals whether interest rates react to unexpected policy events. This reflects the marginal change in the interest rate that is associated with unexpected policy events. If it is not significantly different from zero, the market does not respond any differently to a monetary policy surprise than it does to other unexpected news announcements (Thornton, 2009). An example of this latter unexpected news announcement is identified to be headline news in newspapers (Thornton, 2009).

Before running the regression there has to be a check on outliers in the changes in futures. Thornton (2009) argued to delete all absolute changes of 30 basis points or more if they did not occur at announcement day. He argued that if these changes did not occur on a policy event day, they were not associated with large changes in the Treasury rates. In his data until 2000 there were 25 days excluded from the sample. For the database from February 2000 until June 2007 he took the variables that had absolute changes of 20 basis points or more. The reasoning behind this is that due to no ambiguity in the target rate level, shocks occur less often and are smaller. When excluding for these outliers on days when there is no FOMC meeting, the results in this research become near perfect collinearity. Outliers above a 30 basis points can be deleted without looking at the FOMC statement, but this involves multiple changes on announcement days. By deleting these findings, a number of very important data will be deleted. Due to this and due to the fact that there is already a coefficient on the effects of a monetary policy announcement itself, I have chosen not to delete outliers. This could influence the outcomes.

The next problem that has to be kept in mind is that a regression can be biased if the dataset consists of non-stationary processes. If two unit root processes are independent, it is highly likely that a significant t-statistic will arise when regressing them. The significant result can be either attributable to a trend or to cointegration. A trend shows implied significance when this is not correct, while cointegration means that there is a long-run relation between the variables for which a normal OLS regression is enough to estimate the variables (Wooldridge, 2008). An augmented Dickey-Fuller test (ADF-test) will show whether the variables are non-stationary and, in this case, the order of integration. The order of integration indicates how often the series have to differenced in order to become stationary, with a stationary series being integrated of order zero, I(0). In both the equations 36 and 39 the variables are already differenced once in order to look at the change in the variables. If the ADF test shows that the interest rate and target rate are I(1) processes, the problem of non-stationarity is already solved and the normal OLS regression can be estimated. First differencing is an easy way to generate a stationary series, but it has a drawback. This method filters out low-frequency information, and thus filters out long-run information. The technique to restore this low-frequency information is by incorporating an error correction model which is only possible if there is cointegration (Miller, 1991). A cointegration test will be applied to see whether there are cointegrating equations in the model. The presence of cointegration implies that although the variables are I(1) processes, the residuals of the regression are I(0) processes which implies that there is a long-run equilibrium to which the economic system will converge over time (Wooldridge, 2008). The cointegration test performed is the Engle-Granger cointegration test, since this test is a very simple approach. In order to test whether the variables are cointegrated, a new variable is defined which is the residual of the series. The residual will be tested using an ADF test, for which the null hypothesis is that there is no cointegration between the variables. If this null hypothesis can be rejected, then the variables are cointegrated (Wooldridge, 2008). If the test results show that there is cointegration between the variables, the error correction model can be used to capture the short-run deviations from the long-run equilibrium in this model (Miller, 1991).

The majority of the data used here are obtained from Datastream. This includes the interest rates, the target federal funds rate and the one-month-ahead futures rate. The data on daily US public debt and FOMC statements are the only data that are obtained from another source. The data on debt are from the Bureau of Public debt website of the United States Department of the Treasury[1]. The data on FOMC statements are obtained from the website of the Federal Reserve[2].

7. Outcomes

As mentioned before, the regressions can be plagued by non-stationary processes in the data and then the regression results would imply significance while this would be misleading. In order to check for non-stationary processes, an ADF-test is performed for which the results are

[1] http://www.publicdebt.treas.gov/
[2] http://www.federalreserve.gov/newsevents/press/monetary/2012monetary.htm

shown in table 1 in the appendix. These results show that only the 30 year bonds and the FOMC meeting variable are stationary while all other variables are all integrated of order 1 (I(1) processes). Since the equation is already differenced once, the regression results show no errors.

To start with, a regression is run on equation 36 for which the results are given in table 1. The results indicate that neither the change in debt nor the announced change in the target rate is significant. The positive signs of the announced change in the target rate for the 5 and 7 year maturity are according to theory, but due to the insignificant result these signs are of little value. The R-squared is very small, which indicates that only a very small part of the interest rate change is explained by the change in the debt level and the announced change in the Federal funds target rate. The whole model is insignificant in all four cases as shown by each of insignificant F-statistics. These outcomes are contrary what Cook and Hahn (1989) found, since they found a significant and positive effect of the change in the target rate on the long-term interest rate change. Contrary to this, the findings are according to theory, since the target rate also incorporates expected announcements. These announcements should have no effect on the interest rate, which is proven to be correct in this regression. One explanation for the different results compared to Cook and Hahn (1989) is that these authors only included interest rate changes on days of FOMC announcements in their sample, while this sample contains all days. By implementing all the days and correcting for announcement days by the dummy variable, the regression should only capture monetary policy news. The conclusion can be drawn that neither debt nor monetary policy announcements show a significant effect on the long-term interest rate in this regression.

Table 1: Regression of equation (36)

5 year bonds	Coefficient	Probability
$\Delta \boldsymbol{DEBT}$	-0.000	0.7469
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})$	0.017	0.5102
R-squared	**0.0001**	
F-statistic	**0.7668**	

7 year bonds	Coefficient	Probability
$\Delta \boldsymbol{DEBT}$	-0.000	0.8855
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})$	0.023	0.3734
R-squared	**0.0003**	
F-statistic	**0.6644**	

10 year bonds	Coefficient	Probability
$\Delta \boldsymbol{DEBT}$	-0.000	0.9793
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})$	-0.010	0.6734
R-squared	**0.0000**	
F-statistic	**0.9145**	

30 year bonds	Coefficient	Probability
$\Delta \boldsymbol{DEBT}$	-0.000	0.3592
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})$	-0.017	0.4314
R-squared	**0.0005**	
F-statistic	**0.4761**	

Although the regression did not show significant results, it is still possible that there is a long-run relation. In order to check whether this relation occurs between the variables, an ECM test is performed, which can only be applied when there is cointegration (Wooldridge, 2008). The cointegration test is performed by regressing the change in long-term interest rate on the announced change in the target rate and the change in public debt. A unit root test is performed on the residuals of these equations. As seen in table 2 of the appendix, the test found that there is cointegration between the variables, which opens up the possibility to run the error correction test. The significance levels used are not the ones provided by Eviews in this test, but the levels identified by MacKinnon (1991). The results of the ECM test are shown in table 2.

Table 2: ECM test on equation (36)

5 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM-term	-0.958	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	0.000	0.000***
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-1}$	-0.181	0.000***
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-2}$	-0.098	0.000***
R-squared	**0.483**	

7 Year interest rate	**Lags: 1 1**	
	Coefficient	Probability
ECM-term	-1.002	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	-	-
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-1}$	-0.085	0.000***
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-2}$	-	-
R-squared	**0.485**	

10 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM-term	-1.051	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	0.000	0.022***
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-1}$	0.002	0.913
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-2}$	-0.016	0.396
R-squared	**0.501**	

30 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM-term	-1.066	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	0.000	0.002***
$\Delta \boldsymbol{DEBT}_{t-2}$	0.000	0.812
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-1}$	-0.004	0.823
$\Delta \boldsymbol{ff}_t^*(\boldsymbol{PE})_{t-2}$	-0.009	0.559
R-squared	**0.508**	

*** indicates a 1% significant level

The results above show that a change in debt level is, as opposed to the regression results, almost always significant at 1% in this test. The coefficient is very small and moving towards zero, so the effect is hardly visible, but it is a positive coefficient. The announced change in the target rate is significant here, but only at a 5 year maturity and a 7 year maturity interest rate. This implies that for these maturities, the changed target rate affects the long-term interest rate,

but in a negative way. For longer maturities, this effect is not significant anymore. The error correction term measures the divergence from the long-run relationship showing short-run adjustments (Miller, 1991). This term is significant at every maturity and has a negative sign. This negative sign means that the error term has to adjust back to a lower level which results from the fact that the divergence from equilibrium was too high in the former period. Since the change in the long-term interest rate is explained by all three variables namely, the error correction term, the change in debt and the change in the target rate, an error correction term being too high implies that the interest rate in the former period was also too high. In order to adjust to a long-run equilibrium, the error correction term will fall in the current period in order to obtain long-run equilibrium (Miller, 1991). The R-squared of all the equations is close to 0.5 which can be interpreted as half of the long-term interest rate change being explained by these variables. The amount of lags included differs per maturity, which is based on the lowest Aikake AIC coefficient (Miller, 1991).
The ECM test has shown that there is a long-term relation between the change in target rate, the change in the debt level and the long-term interest rate change, but it cannot capture a significant relation of the target rate individually for the longer time periods. This could be attributable to the fact that the target rate still captures both expected and unexpected announcements. Another model will be tested to account for this.

The second model tested has the federal funds futures rate incorporated into it to account for the surprise component in announcements. The former test results could not find a significant effect of announcements on the long-term interest rate, but perhaps this model can. The model is shown in equation 39. This futures rate is also an I(1) process and there is cointegration found in the equation. The results of the regression are shown in table 4.

Table 4: regression on equation (39)

5 year bonds	Coefficient	Probability
$\Delta \boldsymbol{DEBT}$	-0.000	0.815
$\Delta \boldsymbol{ff_t^{*u}}$	-0.505	0.000***
$(\boldsymbol{PE})$	0.165	0.813
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})$	0.243	0.004***
R-squared	**0.060**	
F-statistic	**0.000*** **	

7 year bonds	Coefficient	Probability
$\Delta \boldsymbol{DEBT}$	-0.000	0.937
$\Delta \boldsymbol{ff_t^{*u}}$	-0.452	0.000***
$(\boldsymbol{PE})$	0.343	0.624
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})$	0.329	0.000***
R-squared	**0.046**	
F-statistic	**0.000*** **	

<u>10 year bonds</u>	Coefficient	Probability
$\Delta DEBT$	0.000	0.963
Δff_t^{*u}	-0.411	0.000***
(PE)	0.186	0.772
$\Delta ff_t^{*u}(PE)$	0.276	0.001***
R-squared	**0.046**	
F-statistic	**0.000*** **	

<u>30 year bonds</u>	Coefficient	Probability
$\Delta DEBT$	-0.000	0.381
Δff_t^{*u}	-0.274	0.000***
(PE)	0.348	0.541
$\Delta ff_t^{*u}(PE)$	0.249	0.000***
R-squared	**0.026**	
F-statistic	**0.000*** **	

*** is significance at a 1% critical value

The regression results for this second model have a different outcome. The coefficient on the change in debt has an insignificant result, which is equal to the regression run on the former model. The coefficient on the measure of news effects (Δff_t^{*u}) is significant for all different maturities and negative. This implies that if the market captures unexpected news which increases the futures rate, the interest rate will decrease. This is not in line with theory and expectations. For longer maturities this coefficient becomes smaller, but still significant. The finding of this negative coefficient in the measure of news effects is controversial to the findings of Thornton (2009), who found the coefficient to be significant and positive in his sample of data until 2000. In his sample running from February 2000 - June 2009 he found these coefficients to be only significant for maturities up to one year, but still having a positive slope. The response coefficient to unexpected policy events ($\Delta ff_t^{*u}(PE)$) is promising since it also shows a significant outcome in this regression and has a positive sign. From this significant result the conclusion can be drawn that the market reacts specifically to a surprise in monetary policy, and reacts positively to this surprise (Thornton, 2009). An increase in the target rate thus increases long-term interest rates. This is as expected from theory, but it is very different from the results found by Thornton (2009). The author found this latter coefficient to be either insignificant or only significant for interest rates having a maturity up to 1 year (Thornton, 2009). For long-term interest rates this author could not find significant results.

An ECM test will also be performed over this model in order to check for a long-term relation and to specify the short-term deviations. The results for this model are shown in table 5 in which the lag length is again determined by the lowest Aikake criterion as explained by Miller (1991). The outcomes of this ECM model show the first lag and the fifth lag, since these outcomes show the most extreme values, both for the coefficient as for the probability. If these two different lags are significant, the intermediate lags are also significant. The results are again fairly different from the outcomes of the regression on this model. The error correction term is significant in all cases and has a negative coefficient. This is in accordance to the former ECM model and theory, as explained earlier. The change in debt is also significant for all maturities but again very small, while it was insignificant in the regression on this model. The measure of the news effect is significant and positive, while this was significant and negative in the regression equation. The measure of the unexpected policy event is significant and has a negative coefficient, while this variable had a positive coefficient in the former regression. As stated here, where the news effect is positive and the policy event announcement shows a negative sign, it implies that the market responds differently to monetary policy news and 'other' news. A positive news announcement will lead to an increase in the interest rate, while an unexpected increase in the target rate will lead to lower long-term interest rates. The R-squared in these equations remains a bit below 0.5 which indicates that a bit less than 50% of the model is explained by these variables.

Table 5: ECM test on equation (39)

5 Year interest rate	**Lags: 1 5**	
	Coefficient	Probability
EMC term	-0.935	0.000***
$(\boldsymbol{PE})$	-0.012	0.987
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-5}$	-0.000	0.001***
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.609	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-5}$	0.078	0.042**
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-1.380	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-5}$	-0.238	0.003***
R-squared	**0.489**	

7 Year interest rate	**Lags: 1 5**	
	Coefficient	Probability
EMC term	-0.746	0.000***
$(\boldsymbol{PE})$	0.447	0.533
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-5}$	-0.000	0.001***
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.589	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-5}$	0.124	0.001***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-1.509	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-5}$	-0.306	0.000***
R-squared	**0.472**	

10 Year interest rate	**Lags: 1 5**	
	Coefficient	Probability
EMC term	-0.793	0.000***
$(\boldsymbol{PE})$	0.206	0.753
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-5}$	-0.000	0.001***
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.489	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-5}$	0.198	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-1.380	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-5}$	-0.280	0.000***
R-squared	**0.481**	

30 Year interest rate	**Lags: 1 5**	
	Coefficient	Probability
EMC term	-0.740	0.000***
$(\boldsymbol{PE})$	0.545	0.343
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-5}$	-0.000	0.001***
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.377	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-5}$	0.089	0.003***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-1.009	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-5}$	-0.264	0.000***
R-squared	**0.485**	

*** is significance at a 1% critical value

The results on the ECM test show that the variables are often significant, but this finding is contradicted by the regression results. The two methods fail to show one uniform conclusion. In both regressions estimated on equations 36 and 39 the debt coefficients were insignificant, while in the ECM models, these coefficients turned out to be significant with only a very small coefficient, being either positive or negative. Negative regression coefficients on debt can indicate that the government has to economize, which affects both consumption and investment, as seen earlier. Lower consumption and investment levels dampen interest rate expectations through the term structure, which results in lower long-term interest rates. Another explanation for the ambiguous results on debt, is that the results are in favour of the Ricardian Equivalent Hypothesis, as explained in the former part of this paper. This would mean that although debt is a significant variable in this model, the increase in public debt is entirely offset by private savings, which is not incorporated in this model. This leads to either a very small coefficient, or even an insignificant debt variable, which is seen in the regression equation. This could be interpreted as changes in debt having no effect on the long-term interest rate. The measure of news in equation 39 is found to be negative in the regression equation, while it is positive in the ECM test. This latter result is in line with the findings of Kuttner (2001) and Thornton (2009) as mentioned above. They find that news effects have a positive relation to interest rates, which is expected by the term structure. It is hard to explain the reason why these policy event variables are negative in the regression, since one would expect little and positive influence. Agents knew the level of the target rates in 2000 and as of May 2004 the FOMC had a 'measured pace' language incorporated in each press statement. This 'measured pace' language indicated that the FOMC would lower the target rate at the next meeting, which it did for each of the meetings that this statement occurred (Thornton, 2009). By January 2006 this statement was discontinued after a modification in 2005. However, the target changes that occurred after January 2006 were all anticipated in advance (Thornton, 2009). An inverse relation between interest rates and these news announcements could be explained by loss of confidence, as explained by Stiglitz (2006). If interest rates rise to untenable levels due to solvency problems in an economy, as for example happened in Spain and Greece, a positive announcement will restore confidence and thus lower interest rates. A negative announcement has the inverse effect and thus will increase interest rates because agents require a higher risk premium. It is possible that both the subprime-mortgage crisis in the US in 2008 and the terrorist attacks in 2001 led to a loss of confidence which is incorporated in the data. The last finding, the effect of monetary policy announcements in equation 39 being significant in both the regression and the ECM test, is very surprising. As mentioned earlier, Thornton (2009) found this variable to be significant only for maturities up to one year. The problem arising here, however, is that this coefficient has a positive sign in the regression, while it has a negative sign in the ECM model. The negative sign can be explained as an increase in the target rate leading to a monetary tightening and thus inflation expectations are adjusted, which leads to lower long-term interest rates (Blanchard, 2005). A positive relation can also be explained, stating that an increase in the target rate increases short-term interest rates. Short-term interest rates set long-term interest rates through the expectations channel and thus these rates will also increase (Bofinger, Reischle, & Schächter, 2001). The result here is still ambiguous, since the ECM model and the regression model show opposite signs.

These ambiguous results can be related to the dataset, since this dataset runs from 2000-2011. There was lots of uncertainty in the market after the terrorist attacks and in the sub-prime mortgage crisis, so in order to decrease this uncertainty, these years can be deleted in the dataset. To check for this hypothesis the tests have to be performed again, but only for the years 2002-2007 in which there were more stable economic conditions. Both the equations 36 and 39 will be estimated again, in case there is a significant result.

Table 6: regression on equation (36) with 2002-2007 data[3]

5 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.088*
$\Delta ff_t^*(PE)$	0.046	0.326
R-squared	**0.002**	
F-statistic	**0.154**	

7 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.058*
$\Delta ff_t^*(PE)$	0.028	0.540
R-squared	**0.002**	
F-statistic	**0.145**	

10 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.205
$\Delta ff_t^*(PE)$	0.013	0.758
R-squared	**0.001**	
F-statistic	**0.434**	

30 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.143
$\Delta ff_t^*(PE)$	-0.021	0.538
R-squared	**0.002**	
F-statistic	**0.271**	

*** is significance at a 1% critical value
** is significance at a 5% critical value
* is significance at a 10% critical value

There is only a small modification in the model, since debt levels are significant for the 5 year- and 7 year maturity. The other coefficients are, just like in the earlier regression results on this equation, still insignificant, so finding this here is not new. The R-squared is still very small and the F-statistic implies that the model is insignificant. The certainty in the market does not lead to more significant regression results. This dataset is also checked for cointegration, since the results on the ECM test could be different. The cointegration test found a positive cointegration which implies that an ECM test can also be performed on this shorter dataset (Wooldridge, 2008).

The new dataset shows that there still is a long-term relation between the variables, and this term is again negative, just as in all former ECM test results. The other results of the test preformed on equation 36 with this dataset do differ from the former ECM results on this equation. The debt level has a negative sign here, while it was positive in the former test. It is still significant. The change in the target rate is positive in this test, which implies that an

[3] Although the dataset is only 6 years, the data still consists of 1564 observations.

increase in the target rate will increase the change in the long-term interest rate. This is according to what is expected by theory. The coefficient is, however, not always significant. From this it can be concluded that there is some added value of performing the ECM test on the shorter dataset with less uncertainty in the market. This effect is especially visible in the change in target rate, but it is still not a very robust result.

Table 7: ECM test on equation (36) with 2002-2007 data

5 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM Term	-0.697	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	-0.000	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-1}$	0.219	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-2}$	0.0723	0.0730*

7 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM Term	-0.698	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	-0.000	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-1}$	0.144	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-2}$	0.036	0.351

10 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM Term	-0.743	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	-0.000	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-1}$	0.239	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-2}$	0.089	0.013**

30 Year interest rate	**Lags: 1 2**	
	Coefficient	Probability
ECM Term	-0.571	0.000***
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-2}$	-0.000	0.000***
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-1}$	0.073	0.017**
$\Delta \boldsymbol{ff}^{*}_{t}(\boldsymbol{PE})_{t-2}$	0.029	0.334

*** is significance at a 1% critical value
** is significance at a 5% critical value
* is significance at a 10% critical value

If there is added value of estimating equation 36 over the period with more certain market conditions, this should also apply to the estimates of equation 39. This regression is shown in table 8 which shows that the results are less significant than they were in the more uncertain market. The debt coefficient is still insignificant and the results still show a negative sign for this variable. This is the same result as found in the former regression on equation 39. The coefficient on news(Δff_t^{*u}) is negative again, but statistically significant for all maturities. This negative sign in the significant models indicates that, although the tests are performed in a relative certain environment, agents still react adverse to news. The measure of unexpected policy events ($\Delta ff_t^{*u}(PE)$) is insignificant in this regression, while it was significant in the more uncertain environment. The R-squared remains to be low, but the entire model is still significant.

Table 8: regression on equation (39) with 2002-2007 data

5 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.161
Δff_t^{*u}	-0.309	0.000***
(PE)	-0.153	0.864
$\Delta ff_t^{*u}(PE)$	-0.038	0.849
R-squared	**0.027**	
F-statistic	**0.000***	

7 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.109
Δff_t^{*u}	-0.336	0.000***
(PE)	-0.163	0.851
$\Delta ff_t^{*u}(PE)$	0.064	0.738
R-squared	**0.032**	
F-statistic	**0.000***	

10 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.330
Δff_t^{*u}	-0.282	0.000***
(PE)	-0.285	0.721
$\Delta ff_t^{*u}(PE)$	0.074	0.673
R-squared	**0.026**	
F-statistic	**0.000***	

30 year bonds	Coefficient	Probability
$\Delta DEBT$	-0.000	0.210
Δff_t^{*u}	-0.222	0.000***
(PE)	-0.043	0.949
$\Delta ff_t^{*u}(PE)$	0.166	0.264
R-squared	**0.022**	
F-statistic	**0.000***	

*** is significance at a 1% critical value
** is significance at a 5% critical value
* is significance at a 10% critical value

These regression results still shown different results, so the this regression will also be complemented with an ECM model, in order to draw the right conclusions. The findings are reported in table 7 for which the reported lags the two most extreme values are, both for the coefficients as for probabilities. The other lag results lay between these reported results. The results of this ECM test are not very different from the results of the ECM test performed on the period 2000-2011. The debt variable is often significant, but also insignificant in some cases. It still remains to be negative and close to zero, while the news variable as indicated by Thornton (2009), (Δff_t^{*u}) is significant and positive. This was the same in the former ECM test on this equation. The measure of unexpected monetary policy news as described by Thornton (2009) ($\Delta ff_t^{*u}(PE)$) remains to be significant but negative, only not for 30 year maturity. For this long-term interest rate, the sign is both positive and significant, but only when one lag is added. From these results the conclusion can be drawn that the debt coefficient is mostly significant, but very small in every equation. The measure of news is significant and positive, so the interest rate will rise when news announcements occur. The specific measure of monetary policy news, on the other hand, is also significant but negative. For this coefficient it does not matter whether these announcements are done in an economic certain period, or in a less certain period. This differs from the findings of Thornton (2009), who found this monetary news coefficient to be insignificant for the long-term interest rates.

Table 7: ECM test on equation (39) with 2002-2007 data

5 Year interest rate	**Lags: 1 4**	
	Coefficient	Probability
EMC term	-0.737	0.000***
$(\boldsymbol{PE})$	0.040	0.965
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.102
$\Delta \boldsymbol{DEBT}_{t-4}$	0.000	0.807
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.833	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-4}$	0.242	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-1.600	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-4}$	-0.477	0.010***
R-squared	**0.465**	

7 Year interest rate	**Lags: 1 5**	
	Coefficient	Probability
EMC term	-0.584	0.000***
$(\boldsymbol{PE})$	0.075	0.933
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-5}$	0.000	0.594
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.820	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-5}$	0.219	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-0.092	0.628
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-5}$	-0.093	0.613
R-squared	**0.469**	

10 Year interest rate	**Lags: 1 4**	
	Coefficient	Probability
EMC term	-0.680	0.000***
$(\boldsymbol{PE})$	-0.043	0.958
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.000***
$\Delta \boldsymbol{DEBT}_{t-4}$	-0.000	0.368
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.603	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-4}$	0.201	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	-2.323	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-4}$	-0.729	0.000***
R-squared	**0.464**	

30 Year interest rate	**Lags: 1 5**	
	Coefficient	Probability
EMC term	-0.554	0.000***
$(\boldsymbol{PE})$	-0.022	0.975
$\Delta \boldsymbol{DEBT}_{t-1}$	-0.000	0.002***
$\Delta \boldsymbol{DEBT}_{t-5}$	0.000	0.318
$\Delta \boldsymbol{ff_t^{*u}}_{t-1}$	0.464	0.000***
$\Delta \boldsymbol{ff_t^{*u}}_{t-5}$	0.145	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-1}$	1.021	0.000***
$\Delta \boldsymbol{ff_t^{*u}}(\boldsymbol{PE})_{t-5}$	0.156	0.285
R-squared	**0.462**	

*** is significance at a 1% critical value

8. Conclusion

The purpose of this paper was to show that monetary policy announcements affect long-term interest rates. The method used took into account both a very simple regression on the target rates, as well as a more enhanced method that included a surprise component. Every equation was first regressed using a normal OLS regression, after which a more complicated ECM model was introduced.

The regression results found that the target rate does not have a statistically significant effect, but the futures rate, which shows the effect of news on the interest rate as identified by Thornton (2009), has a significant effect. This effect is only negative, implying that news that increases the futures rate, will have an adverse effect on the long-term interest rate. The measure of monetary policy announcements as identified by Thornton (2009) is significant and positive for the dataset from 2000-2011, but insignificant for the dataset running from 2002-2007. From the regression results one can conclude that the market responds significantly different to monetary policy announcements, but only under more uncertain market conditions. Other news announcements do affect the change in interest rates, but in an adverse effect, while target rate has no effect on interest rate changes in the regression results.

The ECM tests show fairly different outcomes. All tests show that there is some long-term relation in the equations, but the individual variables show different outcomes. The equation that estimates the target rate shows a significant and positive coefficient for debt in the time period 2000-2011, but this is a negative coefficient in the time period which captures the more certain market conditions, namely 2002-2007. The same applies to the target rate coefficient. This coefficient is significant and negative for the 5 year – and 7 year maturity, while it was insignificant and negative for longer time horizons in the first dataset. In the more certain time span (2002-2007) this variable resulted to be mostly significant and showed a positive sign. The results for the equation capturing the unexpected component of announcements using Federal funds futures, showed more similar results. The long time span 2000-2011 showed the debt coefficient to be negative and significant, which was also seen often in the horizon 2002-2007. A few results were insignificant is this shorter time span. The news announcement is significant and positive in all cases which implies that the interest rate responds positively to news. The monetary policy announcement did not give such similar results. The longer dataset showed this variable to be significant and negative, but this could not be completely retrieved from the 2002-2007 horizon. About half of the results were insignificant for this equation. These insignificant results for monetary policy announcements under more certain market conditions can be attributed to the fact that in a certain environment, more is known and thus less monetary policy announcements are unexpected. The difference between the 2000-2011 database and the 2002-2007 database is still not large enough to state this with complete certainty.

The overall conclusion that can be drawn from these findings is that debt hardly effects the long-term interest rate, but whether this is due to insignificance or to a very small coefficient, is difficult to say. This provides some evidence for the Ricardian Equivalence Hypothesis, stating that debt levels do not affect interest rates (Ussher , 1998). The target rate is unlikely to affect the long-term interest rate which was expected in advance. This target rate includes both expected and unexpected announcements while the former type should have no influence on the interest rate as explained by Kuttner (2001). The last two variables, the measure of the reaction to news and the measure of the reaction to a monetary policy announcement as identified by Thornton (2009), show unclear results. It is obvious that there is an effect of both measures, since the coefficients were often significant. The direction the coefficients, on the other hand, remain to be unclear. It seems to be that the measure of news has a positive coefficient, while the measure of monetary policy announcements has a negative coefficient. The negative coefficient can be explained by the fact that an announcement about monetary policy tightening leads to an upward adjustment of inflation expectations and thus a downward shift of the long-term interest rate. The negative effect of monetary policy announcements is explained by this theory, but it remains to be against the expected outcome. What is clear, and controversial with respect to earlier research, is that there is a significant effect of the news on monetary policy. This is a very promising result.

The findings here differ from the literature, but this is partly attributable to the fact that an ECM test is used. To my knowledge, there is no other research performed on this topic that includes the ECM test. Another explanation for these results differing from earlier research is that I could not delete any outliers which happened in the work of Thornton (2009). It was impossible to keep them out, while still implementing the dummy variable in the regression. When deleting these outliers, perfect collinearity arose when regressing the dataset with the dummy on FOMC announcements. Due to the fact that I found the monetary policy announcement variable more desirable than deleting outliers, I did not delete shocks of over 20 basis points arising on days when there was no monetary policy announcement. An improvement can also be made to insert more announcement indicators such as headline news and in inflation expectations. Thornton (2009) included some of these announcement indicators and found it to improve his dataset.

9. References

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10. Appendix

Table 1

Augmented Dickey-Fuller test results 2000-2011.

	Model with target rate		Model with federal funds futures	
	Level	**First difference**	**Level**	**First difference**
Debt	1.0000 (4.35)	0.0000*** (-12.13)	1.0000 (4.35)	0.0000*** (-12.13)
Federal Funds Target /Futures	0.7917 (-0.89)	0.0001***	0.5677 (-1.433)	0.000*** (-6.498)
FOMC meeting	0.000*** (-22.75)		0.000*** (-22.75)	
5 Year bonds	0.3941 (-1.77)	0.0000*** (-41.99)	0.3941 (-1.77)	0.0000*** (-41.99)
7 Year bonds	0.2007 (-2.22)	0.0000*** (-41.32)	0.2007 (-2.22)	0.0000*** (-41.32)
10 Year bonds	0.1047 (-2.55)	0.0000*** (-41.63)	0.1047 (-2.55)	0.0000*** (-41.63)
30 Year bonds	0.0199** (-3.20)		0.0199** (-3.20)	

*** is significance at a 1% critical value and ** is significance at a 5% critical value. The p-values are displayed with the accompanying t-statistics between brackets.

Table 2

Engle-Granger cointegration test results for the equation (36) 2000-2011.

	t-Statistic
5 Year bonds	-4.461***
7 Year bonds	-4.444***
10 Year bonds	-4.572***
30 Year bonds	-4.234**

*** is significance at a 1% critical value
** is significance at a 5% critical value.

Table 3

Engle-Granger cointegration test results for the equation (39) 2000-2011.

	t-Statistic
5 Year bonds	-4.112**
7 Year bonds	-4.359***
10 Year bonds	-4.488***
30 Year bonds	-4.194**

*** is significance at a 1% critical value
** is significance at a 5% critical value.

Table 4

Augmented Dickey-Fuller test results 2002-2007 with 1560 observations.

	Model with target rate		Model with federal funds futures	
	Level	**First difference**	**Level**	**First difference**
Debt	0.8154 (-0.811)	0.0001*** (-44.013)	0.8154 (-0.811)	0.0001*** (-44.013)
Target /Futures rate	0.9270 (-0.268)	0.0000*** (-39.600)	0.9127 (-0.364)	0.0000*** (-39.189)
5 Year bonds	0.4575 (-1.648)	0.000*** (-39.015)	0.4575 (-1.648)	0.000*** (-39.015)
7 Year bonds	0.2209 (-2.161)	0.000*** (-39.350)	0.2209 (-2.161)	0.000*** (-39.350)
10 Year bonds	0.0834* (-2.649)	0.000*** (-38.962)	0.0834* (-2.649)	0.000*** (-38.962)
30 Year bonds	0.0512* (-2.854)	0.000*** (-38.940)	0.0512* (-2.854)	0.000*** (-38.940)

*** is significance at a 1% critical value, ** is significance at a 5% critical value and * is significance at a 10% critical value.
The p-values are displayed with the accompanying t-statistics between brackets.

Table 5

Engle-Granger cointegration test results for the equation (36) 2002-2007.

	t-Statistic
5 Year bonds	-2.954
7 Year bonds	-3.224*
10 Year bonds	-3.265*
30 Year bonds	-3.212*

*** is significance at a 1% critical value
** is significance at a 5% critical value
* is significance at a 10% critical value

Table 6

Engle-Granger cointegration test results for the equation (39) 2002-2007.

	t-Statistic
5 Year bonds	-3.105*
7 Year bonds	-3.269*
10 Year bonds	-3.256*
30 Year bonds	-3.133*

*** is significance at a 1% critical value
** is significance at a 5% critical value.

Table 7

T-statistic values

$P(c) = \beta_\infty + \frac{\beta_1}{T} + \frac{\beta_2}{T^2}$ (MacKinnon, 1991)

N	Variant	Level	Obs.	β_∞	(s.e.)	β_1	β_2
1	no constant	1%	600	−2.5658	(0.0023)	−1.960	−10.04
		5%	600	−1.9393	(0.0008)	−0.398	
		10%	560	−1.6156	(0.0007)	−0.181	
1	no trend	1%	600	−3.4336	(0.0024)	−5.999	−29.25
		5%	600	−2.8621	(0.0011)	−2.738	−8.36
		10%	600	−2.5671	(0.0009)	−1.438	−4.48
1	with trend	1%	600	−3.9638	(0.0019)	−8.353	−47.44
		5%	600	−3.4126	(0.0012)	−4.039	−17.83
		10%	600	−3.1279	(0.0009)	−2.418	−7.58
2	no trend	1%	600	−3.9001	(0.0022)	−10.534	−30.03
		5%	600	−3.3377	(0.0012)	−5.967	−8.98
		10%	600	−3.0462	(0.0009)	−4.069	−5.73
2	with trend	1%	600	−4.3266	(0.0022)	−15.531	−34.03
		5%	560	−3.7809	(0.0013)	−9.421	−15.06
		10%	600	−3.4959	(0.0009)	−7.203	−4.01
3	no trend	1%	560	−4.2981	(0.0023)	−13.790	−46.37
		5%	560	−3.7429	(0.0012)	−8.352	−13.41
		10%	600	−3.4518	(0.0010)	−6.241	−2.79
3	with trend	1%	600	−4.6676	(0.0022)	−18.492	−49.35
		5%	600	−4.1193	(0.0011)	−12.024	−13.13
		10%	600	−3.8344	(0.0009)	−9.188	−4.85
4	no trend	1%	560	−4.6493	(0.0023)	−17.188	−59.20
		5%	560	−4.1000	(0.0012)	−10.745	−21.57
		10%	600	−3.8110	(0.0009)	−8.317	−5.19
4	with trend	1%	600	−4.9695	(0.0021)	−22.504	−50.22
		5%	560	−4.4294	(0.0012)	−14.501	−19.54
		10%	560	−4.1474	(0.0010)	−11.165	−9.88
5	no trend	1%	520	−4.9587	(0.0026)	−22.140	−37.29
		5%	560	−4.4185	(0.0013)	−13.641	−21.16
		10%	600	−4.1327	(0.0009)	−10.638	−5.48
5	with trend	1%	600	−5.2497	(0.0024)	−26.606	−49.56
		5%	600	−4.7154	(0.0013)	−17.432	−16.50
		10%	600	−4.4345	(0.0010)	−13.654	−5.77
6	no trend	1%	480	−5.2400	(0.0029)	−26.278	−41.65
		5%	480	−4.7048	(0.0018)	−17.120	−11.17
		10%	480	−4.4242	(0.0010)	−13.347	
6	with trend	1%	480	−5.5127	(0.0033)	−30.735	−52.50
		5%	480	−4.9767	(0.0017)	−20.883	−9.05
		10%	480	−4.6999	(0.0011)	−16.445	

Source: MacKinnon (1991)