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Financial Markets Interactions:
the impact of US Monetary Policies on Domestic Securities

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Abstract

This paper tries to address the effects of a modification in the monetary decisions over different kinds of securities. Specifically, starting from the adoption of model able to distinguish among the different components of the change effect over the securities, the aim of the study is to evaluate such impact and then checking if it is possible to derive a strategy in order to implement such idea into a trading portfolio. The linear model will be tested over the return of debt and equity securities, focusing on United States Treasuries and to the behaviour of the Standard & Poor 500 Index. The last chapter of the paper will then present related results.

MONETARY POLICIES ARE THE INSTRUMENT through which Monetary Authorities reach specific objectives, representing then a crucial aspect for the movement and the development of the economy of a country. Specifically, monetary policies implement Authorities' vision for future years, and are generally addressed to sustain economic growth and employment rate while controlling the level of inflation and the movement in prices. The Federal Fund Rate management represented the standard instrument through which the American Federal Reserve implemented its view over the economic environment in the majority of 20th century years.

Even if Monetary Authorities' objectives are generally addressed to the "real side" of the economy, these choices firstly affect financial markets behaviours. Indeed, the effect that the announcement of a modification in the monetary decisions by the Federal Reserve has a sensible impact over securities prices. It has to be noticed that several studies were performed with the aim to precisely state how the different securities were about to answer to this kind of modifications, several of them using a Vector Autoregressive approach (VAR), while other analysing movements in the rates using market-related data. The choice to use this second approach rather than the VAR-based one can be justified in the need to catch the daily movements experienced by prices as to get the necessary data to exploit daily evidences on the market into a trading strategy. Traditionally VAR models are based on longer period observation, requiring then a de-averaging of the data achieved through the calculation made to translate the impact into a framework useful for trading.

The choice of implying a linear model based on Fed Fund Rate rather than the use other market based metrics is therefore supported even by the studies of Gürkaynak, Sack and Swanson (2002)[1], who proposed a testing framework on the various model used in assessing the forecasting ability that the several rates can exercise over various security markets. Specifically the test are made over the rates that are used to anticipate policy shocks, which are those movements that were not predicted by market operators in advance.

In the following paragraphs will be briefly presented the characteristics of the instruments used in order to gauge the monetary policy decisions, and then their impact over the different markets.

[1] Refet S. Gürkaynak, Brian Sack, and Eric Swanson, **"Market-Based Measures of Monetary Policy Expectations",** Division of Monetary Affairs Board of Governors of the Federal Reserve System, 2002

The impact of monetary policies

The setup of the study

The Fed Fund Rate an instrument under the direct control of the Federal Reserve, which through its modifications applies its policies and pursue its objectives, mainly addressed to the managing of macroeconomic variables such as inflation, occupational levels and in the end economic output of the United States. The direct control and the broad use by the Central Bank made it as one of the favourite mean addressed to gauge monetary preferences and changes by scholars and analysts.

Given the specific nature of the intervention of the American Central Bank on the Fed Fund Rate, and the way it can settled, another important feature of the analysis is the timing on which the rate can be changed (or not). The market expects new information about the Fed Fund Rate to be disclosed after the meetings of the Federal Open Market Committee, which are usually scheduled and announced; indeed FOMC meetings are also the place in which a changes are set, this means that the market achieve the knowledge of the Fed Fund Rate future. This peculiarity imposes to follow an event driven methodology, studying securities’ behaviours around specific dates.

The study is addressed to the estimation of the portion of the change to be addressed to changes in the fed fund rates, by that a linear regression and an OLS estimation of the coefficient has been chosen as the more pertinent methodology to the study. More specifically the linear regression used to estimate the impact of a change in the monetary policy over the securities follows a formula having as structure:

$$R_t = \sum_{i=0}^{n} \beta_i X_i + e_t$$

Where:

R_t: security returns;

β_i: i-th coefficient

X_i: i-th regressor

$X_0 = 1$

e_t: error term.

The regressors taken into account are measures of the change in the Fed Fund Rate, distinguished by the ability of the market to forecast the change in the Fed Fund Rate. The next paragraph contains a precise analysis and a more deep explanation of the estimation and function of the different regressors, that are one of the core aspects of such analyses.

Estimating the independent variables of the study

As already said in the previous sections, a change in monetary policies putted in place by a Central Bank has a direct impact on financial markets through several different channels, before passing to "real" economy and affecting the different indices to which these choices are addressed. As already pointed out by previous studies, such as the one by J.Campbell, C.Pflueger and L.Viceira (2012)[2], or R. Gurkaynak, B. Sack and E. Swanson (2002)[3] , Central Bank interventions have a

[2] John Y. Campbell, Carolin Pflueger, and Luis M. Viceira, **"Macroeconomic Drivers of Bond and Equity Risks"**, 2012

[3]Refet S. Gürkaynak, Brian Sack, and Eric Swanson, **Ibid**.

large and significant impact over financial markets especially in the short time horizons, going from 5 months to some quarters. The immediate impact this changes have can be the subsequence of a partial or total lack of information efficiency, which brings the markets to overreact to some choices, before to get back to a new equilibrium level.

The main contribution to the empirical estimation of such efficiency lack comes from the studies of K. Kuttner (2000)[4] , and B. Bernanke and K. Kuttner (2005)[5] , in which is pointed out a methodology to separate the expected and the unexpected component of the impact that monetary policies can have over financial markets. In order to have a measure of the unexpected component, the measure used by the paper is to take into account the daily change of the one-month future fed fund rate, averaged over the month's days, in order to gauge the correct impact it can have over the time set.

The formula used is:

$$\Delta R_{un} = \frac{dm}{(dm - t)}(f_t^1 - f_{t-1}^1)$$

Where:

- ΔR_{un}: unexpected effect;
- dm: number of days in the month;
- f^1_t: price of the future on day t;
- t: day.

Problems arise when the calculation takes into account the value of the future on the last day of the month, things that will make the multiplier as an integer divided

[4] Kenneth N. Kuttner, **"Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market"**,2000

[5] Ben S. Bernanke and Kenneth N. Kuttner**, "What Explains the Stock Market's Reaction to Federal Reserve Policy?"**, The Journal of Finance, Vol. 60, No. 3 (Jun., 2005), pp. 1221-1257

by zero. In order to avoid errors in the estimation of the unexpected effect, when such event occurs the delta will be calculated taking into account the price of the future on the first day of the subsequent month and adjusting accordingly the multiplier. To calculate the portion of the change that in this kind of estimation can be addressed as “expected” by the market (called Re), the formula will be simply the difference between the change in the actual Fed Fund Futures target rate set by the Federal Reserve and the unexpected component, calculated as shown above:

$$\Delta R_e = \Delta R_i - \Delta R_{un}$$

Where:

- ΔR_e: expected effect
- ΔR_i: target rate change

The price of a future can be considered as a good substitute for gauging the expectation of financial operators over the underlying security. As already pointed out by K. Kuttner in its papers, the one-month Fed Fund Future represents an efficient statistical measure to forecast future levels of the fed fund rate, since estimation errors doesn’t seem to be correlated with other known variables. The unexpected component estimated through the formula presented before represents the amount associated to a new stream of information to the market. As said before a lack in information efficiency or in the timing of adjusting to a new change would imply that such kind of information would have an effect on other securities, making their price changing and subsequently adjusting to the new equilibrium level. A non-immediate adjustment to the new equilibrium level would result in a time window in which there is a gap between the “true equilibrium price” of a security, and the actual price, making trading opportunities to arise.

Timing Issues

Given the particular nature of the Fed Fund Rate it seems appropriate to give a deeper analysis of its formation, and the timing aspects related to it, which represent another core factor of the regression. The appropriate specification of the timing of the formation of the variables behind the regressors becomes determinant when the main aim is to analyse the existence of an effect linked to a lack of information to the market. This paragraph is addressed, then, to give some information on Fed Fund Rate formation in order to justify and rationalize the choices made in analysing the effect of the rate over the various financial markets.

As already said in the introductory chapter, it is the Federal Open Market Committee (FOMC) the institutional organization in charge of determining the level of the Fed Fund Rate. The FOMC indeed decide whether to change the interval in which the rate to float or to maintain it steady on the basis of the actual conditions of the real economy and in the end of financial markets. Due to the importance and the impact that this kind of decisions may have on an entire nation behaviour it is necessary to ensure an elevated expertise and an appropriate level of balance inside the decision-making entity. The FOMC is structured, indeed, as to include the seven members of the Federal Reserve Board, the President of the New York FED, and others eleven Federal Reserve Bank Presidents. Within this last group only four among eleven member are chosen as voting participants, while the others should attend the meeting with consulting powers only; the four voting entities change yearly on a rolling basis as to guarantee a correct representation of the different Central Banks.

The Federal Open Market Committee should meet at least four times a year, but since 1981 the number of meetings has been usually around eight, with the opportunity to set up additional meeting whenever extraordinary events occur, and the markets need intervention. In the following analysis this distinction will be considered as a matter of interest, indeed it is rational to expect that since extraordinary meetings occur during extremely stressful economy condition and with the specific aim to try to mitigate adverse effects, market participants would more likely forecast a rate change during those events.

The first timing aspect to be considered in the analysis is that is the Federal Open Market Committee that after its meetings announces the decision to put in practice changes in the level of the Fed Fund Rate, as already said in the first paragraph of the chapter. This setup has been true since 1994, when the Federal Reserve decided to give the markets more information, and to announce every change in its policies over the Fed Fund Rate. More specifically, until 1994, changes in the Fed Fund Rate where not always corresponding to a meeting of the Federal Open Market Committee; and the announcement of a change in the monetary policy was given when markets where already open and the Fed Fund Rate was already embodying the new level. Given these premises, it is natural to expect that the first price reflecting a change in monetary policies was the opening one, and by that, the first gap that can be noticed was in the close-to-open returns. From that year on, the FOMC announcement comes just after the meetings, by that the closing price of the meeting can be considered as the first one that accounts for the monetary policy decision. This time structure of announcement would have further implications, that would be better specified in the following paragraphs, especially the ones in which the analysis takes into account more volatile securities.

The second aspect is related to the availability of the data, as said in the previous paragraph the measures used as regressors are estimated on the Fed Fund Rate Futures with one month horizon. Futures on Federal Fund Rate have been traded for the first time in 1989 on the Chicago Mercantile Exchange, and the CME is still the market where this instrument is placed. This implies that 1989 is the first year that can be taken into account to put in practice this analysis. Other availability problems are related to the formation of the single indices.

One last concern about the timing aspects of the Fed Fund Rate impact over the different kind of securities arises when focusing on the interval chosen by the FOMC. In the years going from 2008 to 2015 the Committee chose zero as lower boundary for the Fed Fund Rate. This choice was coupled with a set of monetary policies aimed to sustain the economy even further, such as the Forward Guidance and the Quantitative Easing. In this kind of scenario using the rates of futures on the Fed Fund Rate as the only proxy for monetary movements would thereby be a limit in estimating the impact that monetary policies can have on the financial markets and on the various set of Securities.

Security Analysis

As said in the introductory paragraph to this section, the most direct effect that monetary policies have over the economy is reflected by financial markets. It is rational to suppose that operators on the financial environment would try to adjust their position as soon as possible according to such major change.

To analyse the impact of such change the independent variable that should be considered are returns, and how they change according to movements in macroeconomic variables.

In the next paragraph the analysis on the effect of the expected and the unexpected component of the Fed Fund Rate variation would take into account a different set of securities, starting from Treasuries and moving to stocks.

Treasuries: T-Bills

The analysis on zero-coupon treasuries takes into account the yield variation of this kind of securities over a wide set of time horizons, starting from the ones with closer maturities, 1-month Treasury Bills, going on up to 12-months maturity Treasuries.

The Yield to Maturity represents the return that it can be achieved by holding the bond up to its maturity. It represents the rate at which the face value is discounted as to obtain the price of the zero coupon bond; usually the maturity considered is one year even for shorter-terms bonds. By the way, the YTM can be considered as an internal rate of return on a bond investment, supposing that the bond buyer decides to reinvest all the payments that the bond does into the same security. It should be noticed that this kind of assumption does not hold for zero-coupon bonds, as the only payment they do is the reimbursement of the face value at maturity, and that this kind of treasuries have a very short time horizon.

The decision on setting the yield to maturity for on-the-run treasuries is extremely linked to the price formation process, that on this kind of security tend to be quite specific and differs from the majority of the other securities' one. More specifically this process is based on a two-stage setup, with an auction-like layout; furthermore, each stage is specifically addressed to investors of different natures and investment power, and even the bidding process is non-homogeneous for the two groups. The first stakes is based on competitive bidding, where large investors compete in order to obtain the best possible bids, given the amount of money they wish to invest in Treasuries by submitting the discount rate for the investment. The second component is aimed for individuals and smaller investment firms, which issues non-competitive bids, whose discount rate depends on the average of the competitive ones. For what concerns off-the-run T-Bills, they are traded on secondary market and their price formation process follows market rules. By the

United States Treasuries represents one of the safest instrument for every kind of investors, and this holds even for T-Bills. Even if this kind of securities do not ensure a coupon to their holder, they are backed from a top-ranked economy and they have a convenient low duration, as their maturity is extremely low and close in time.

In order to analyse the impact of a change in the Treasuries returns we will apply the setup presented in the introductory paragraph of the chapter, defining the linear regression formula as:

$$R_t = 1 + \beta_1 R_{un,t} + \beta_2 R_{e,t} + \varepsilon_t$$

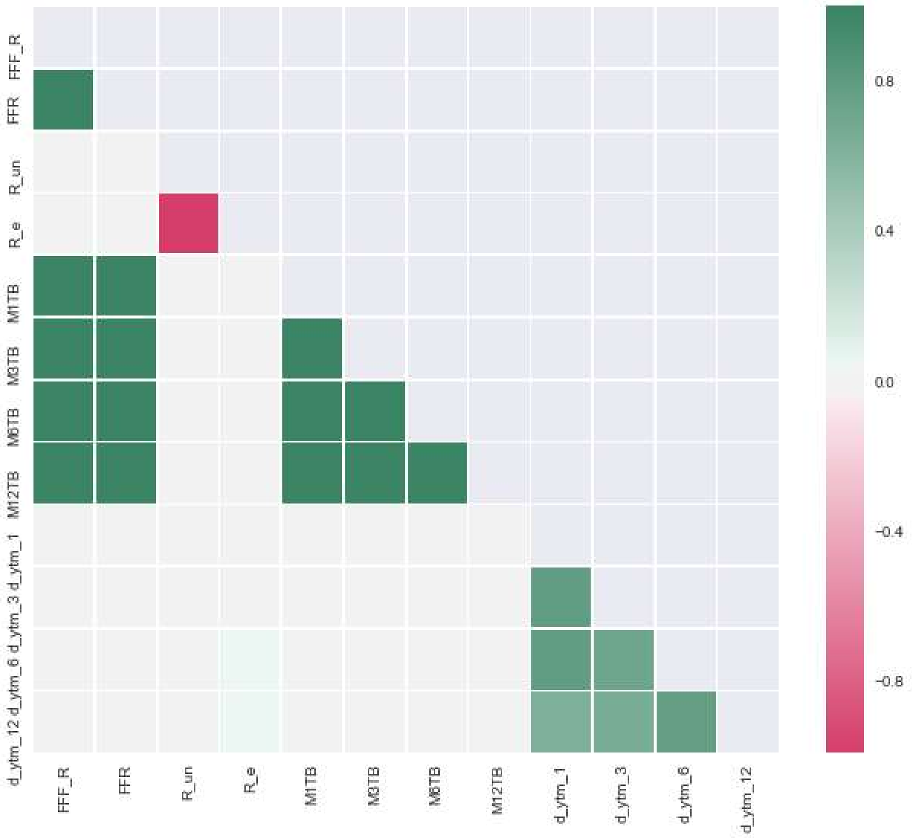
Zero Coupon Treasuries main feature is the Yield to Maturity (YTM). Anyway, the return estimated in the analysis are specifically related to event days movements; the focus will be then posed on daily returns, or daily variations of the YTM.

This Delta in YTM represent only an approximated measure to estimate returns on bonds, but this kind of analysis can be a first step in assessing the existence of a relationship between the security and the selected independent variables.

Treasury Bills: Correlation Analysis

The first component necessary to structure a linear regression analysis is figuring out if it exists a relationship between the dependent and the independent variables. In order to get it at a first glance, the following graph shows the correlation coefficient that stands between them. This kind of analysis is a first step in order to identify the trends affecting the variables, allowing giving a more precise direction to the analysis, at least at a macro level.

The first correlation analysis made takes into account daily observations going from the last months of 1988 up until 2019, collecting then approximatively 5825 observations.



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Graph 1 - Correlation Heatmap between delta-yields and independent variables over the entire sample of observations (1988-2019)

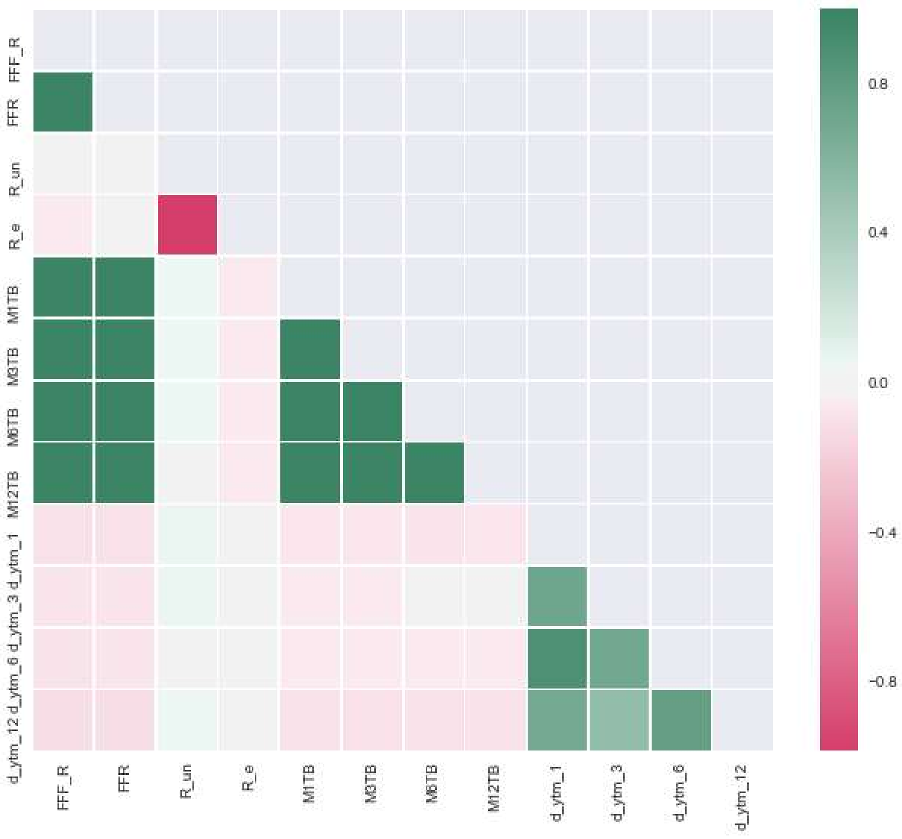
The graph takes into account several different variables:

- **FFF_R**: Fed Fund Futures Rate;
- **FFR**: Fed Fund Rate;
- **R_un**: unexpected component in Target Fed Fund Rate Change;
- **R_e**: expected component in the Target FFR Change;
- **MxTB**: YTM for a US Treasury with maturity of "x" months;
- **d_ytm_x**: daily change in the YTM of a US Treasuries with a maturity of "x" months.

The rationale behind the graph is that the square in the intersection of the two variables assume a different colour according to their correlation level. In case of positive correlation, the square assumes the green colour, while in case of negative correlation the square turns red ; in both cases, the darker the colour, the higher the correlation coefficient.

This high scope dataset contains the whole sample of daily observations of bonds Yields to Maturity and Federal Linked Securities, as well as all the daily estimations made to create the regressors. The correlation heatmap shows that there exists a high positive correlation between the Yield to Maturity of each one of the zero-coupon bonds taken into account by the study and both, the Fed Fund Rate and the Futures calculated on its value, consequently. Although on this everyday basis, the relationship between the change in yields (d_ytm_x) and the expected and unexpected components of the change in the Fed Fund rate Target. This result is reasonable, even if it seems in contrast with the aim of the study, indeed it would not be reasonable for the market to expect a change in monetary policies in days in which there is not scheduled a meeting of the Federal Open Market Committee. The same rationale applies to the unexpected component. The overall sample seems than less relevant to the study setup, as the data observed during FOMC meeting dates have been diluted among the more than 5800 observations.

In order to achieve an higher level of detail, and to focus only on the specific days on which the FOMC has the ability to apply its decisions in terms of monetary policies, a more significant sample over whom to run the correlation analysis is the one formed by the whole number of the ending days of the Committee meetings. In this case, the number of observations over the entire dataset is reduced to only 171 event days, which anyway may contain some outliers. As said before, even if the number analysed in this case is sensibly lower, the relevance of these dates for the monetary policies are much higher than on the “normal ones”, making the information carried on by these days much important than the one provided by an higher set of observations.

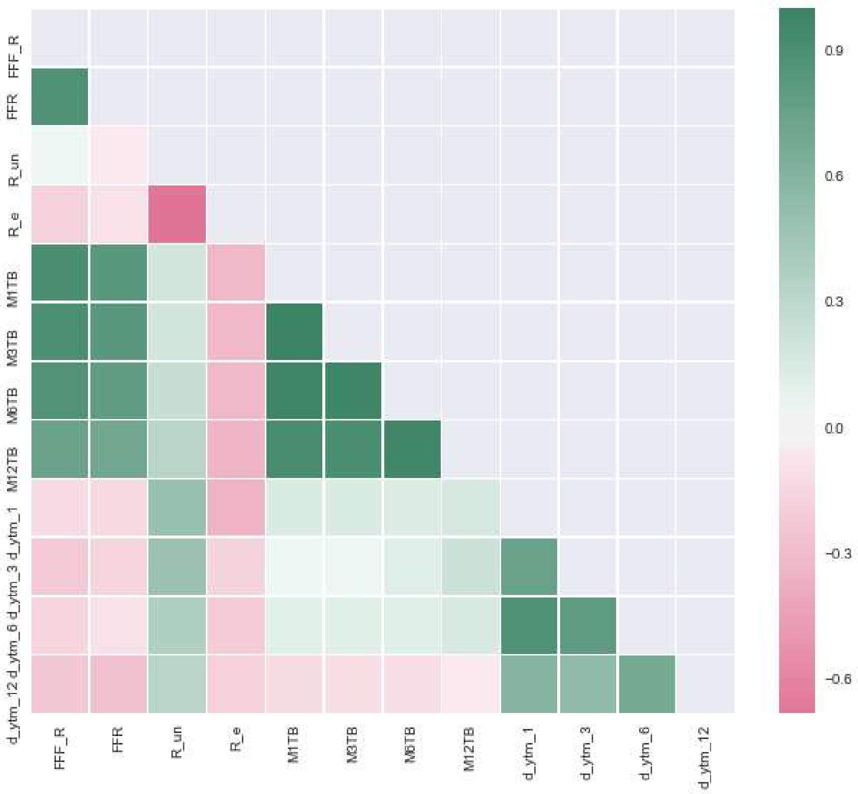


Graph 2 - Correlation Heatmap between delta yields of Treasury Bills and independent variables over the sample containing all the FOMC meetings ending days in the sample (1988 – 2019)

The heatmap shows that the reduction of the sample to only those days that can be considered relevant for the decision of monetary policies increases the correlation among the different variables. In this dataset the difference in the YTM of the several Treasury Bills starts to show the existence of a correlation with the other rates. As predictable, in this case, the correlation has an opposite sign than the one simply linked to the Yield to Maturity of the bonds. For what concerns the regressors' side, while the unexpected component shows a slightly positive correlation coefficient with the dependent variables, the expected one still do not seems to have any correlation with the interesting variables.

Investigating the reasons that brings this lack in the relevance of the correlations coefficient, a great part of it can be attributed to some timing bias that affects the sample. Indeed, as already anticipated in the paragraph dedicated to the timing issues affecting the analysis there are two major shortcoming on the construction of such sample and that affect the estimation. The first thing to notice is that the Federal Open Market Committee started to implement the change of Fed Fund Rate on the Ending Day of its meeting only from 1994, while on the previous years the announcement of the target change was leaved for the day after. The second and more relevant aspect of such timing bias is strictly linked to the years of the financial crisis. As already said, many problems in this specific kind of estimation arises from the zero lower bound of the Fed Fund Rate and from its maintenance over the years.

The last sample on which this correlation heatmap is made up by the ending days of the FOMC meetings in the interval 1994 – 2008.

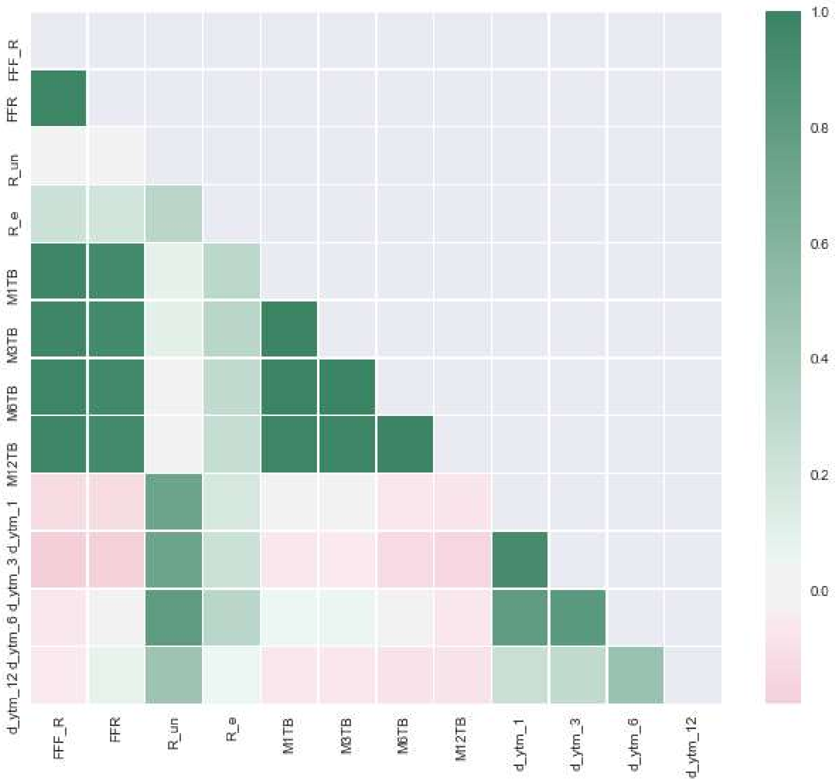


Graph 3 - Correlation Heatmap between delta yields of Treasury Bills and independent variables over an observation sample containing all the FOMC meetings ending days in those times that were homogeneous from a policy disclosure point of view, up to the financial crisis (1994 – 2008)

Moving the focus on this specific interval the results shows clearly a much higher presence of significant correlation coefficients, especially for what concerns the variables addressed to perform the study. Both the indicators of the monetary policy effect, Run and Re show a relationship with the variation in the yield of the treasuries. Specifically the unexpected effect on change days seems to be positively correlated with the difference in yields, with a coefficient that is higher for both the shorter term T-Bills considered in the study, whereas it declines for longer term securities. On the other side, analysing the component of the change that can be considered expected by the market, it has a negative correlation with the change in yields. This second aspect seems obvious by construction, as the expected component is calculated as a variation in the target (that the market could reasonably expect as a 0.25 modification in the rate), and the unexpected component for which has been already proven the positive effect over the change in rate.

An aspect that should be noticed is the difference in the correlation that the two regressor have on the Raw Yield to Maturity of the different securities. The expected component of the target change shows a quite consistent negative correlation with the Yields to Maturity of every single bond, independently from its maturity. On the other side is possible to see that the unexpected component present a different outcome in its correlation with the rates presented by the different bonds. Indeed, analysing the case of the unexpected effect, the correlation coefficient varies according to the security, with the rate of yearly T-Bills that seems more sensitive to the regressor rather than the one of shorter maturity. This consideration does not hold for the differences in yields, indeed the unexpected effect presents a much stronger correlation with this kind of variation, but the delta-yields presented by shorter maturity T-Bills seem to be more responsive than longer ones.

The last sample on which to run the correlation analysis is the one containing the daily observations in the "crisis time interval", in particular referring to all those observations on the FOMC meeting dates occurred after 2008 and the set as the lower bound of the target rate the zero value. The next sample contains observation of about 70 event days going from 2008 up to today, and has the aim of determining how the relationship evolved under the particular conditions experienced by the market in those specific times. As already told before, the financial distress and the high impact that monetary policies had on the market may be a trigger for a change in the responsiveness of Treasury Bills according to the expectation of a change in monetary policy.



Graph 4 - Correlation Heatmap between delta yields of Treasury Bills and independent variables over an observation sample containing all the FOMC meetings ending days in those times that followed the financial crisis of 2008, arriving up to 2019 (2008 – 2019)

The graph shows a sensible change in pattern for a wide range of variables, but especially for what concern the "expected" component of the change. The independent variable "R_e" experiences a shift in its behaviour, with the correlation coefficient that moves from negative to positive sign for what concern the overall spectrum of Bills taken into account; although the magnitude of such coefficient does not suggest a relevant connection between the variable and the change in yields. On the other side, while remaining positive, shows a sensible increase in magnitude, especially for maturities up to six months. The heatmap, indeed, shows high positive correlation, which suggest a stronger significance in the linear relationship in the study over this last sample of daily observations.

From this correlation analysis we can say that the sample on which the analysis is performed strongly affect the response of the Treasuries Bills to such measures of action in the monetary policies, and more specifically that the timing issues presented in the dedicated paragraph strongly affect the study results. While if the analysis of the Federal Open Market Committee meeting dates strongly impact the significance of the study, with the correlation graph related to it starting to present some relevance across the variables in study. Nevertheless, analysing the records related to the years of the financial crisis, the correlation analysis shows a sensible increase of the coefficient, especially for the unexpected component of the change, while the "expected" one experiences an inversion of its behaviour, but it shows a correlation level that does not seem significant to the analysis extent. According to this low level of the fundamental component of the change is possible to imagine two different scenarios, or that the financial conditions made the market react in a different way to Fed Fund Target change (or level maintenance) announcements, or that other policies affect operators' behaviour and expectations.

Treasury Bills: The Linear Regression Analysis

In order to give practical consequence to the hypothesis presented in the previous paragraph based on the correlation results, in this section the analysis will be structured as OLS Regressions, and run over the several samples presented before.

The Linear Regression analysis will be structured not only differentiating the observation samples on the basis of the years of observation, but even on the distinction between normal and event days (FOMC meeting ending days).

Before starting with the specification of the OLS regression over the different securities delta yields, an Augmented Dickey-Fuller Test has been performed on the variables. The result ensures that all the variables taken into account by the test are stationary, and then that there exists a correct specifications for the various errors that are estimated in the linear models.

The first regression takes into account the entire sample of observations on the delta yield, the daily data on which the model has been performed in order to reach an estimate of the day-to-day impact amount at 5825

COMPLETE SAMPLE – 1988-2019				
Dependent Variable	**d_ytm_1**	**d_ytm_3**	**d_ytm_6**	**d_ytm_12**
Intercept	- 0.0011* (0.001)	- 0.0011* (0.001)	- 0.001* (0.001)	- 0.0012** (0.001)
R_un	0.025 (0.107)	0.0293 (0.122)	0.021 (0.113)	0.0214 (0.101)
R_e	0.0255 (0.107)	0.0291 (0.121)	0.0228 (0.113)	0.0233 (0.101)
R^2	**0.004**	**0.005**	**0.005**	**0.004**

*Table 1 - OLS Regression with the delta-yield of various maturity Treasury Bills as dependent variables (d_ytm_x) over the entire sample of daily observations (1988-2019). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

As for the correlation graphs, d_ytm_x stands for the variation into the Yield to Maturity of bonds where x stands for the month to maturity.

For all the analysed securities, the table shows a quite poor performance of the linear approximation through the selected regressors in correctly specify the independent variable. The determination coefficient is extremely low for every one of these four different Treasuries, showing that the model do not give a sufficient specification of the dependent variable, and so that the regressors would not be useful in processing the information. From the coefficient estimation, it is possible to gather that a unitary change in the (weighted) difference in the rates of futures affects for just 2-3 bp the difference in yield. Furthermore, the statistical significance level of each of the estimated coefficient do not even reach the 10%, making the model not useful in determining yields behaviours.

According to the timing considerations made in the dedicated paragraph, a more consistent approach to this specific kind of analysis would be the one specifically addressed to the days when the event of monetary policies took place. The next sample would indeed take into account the days of changes in the Target Rate for the years prior to 1994, and the ones of the Federal Open Market Committee meetings for all the years going to 1994 to 2019. The number of observation moves from more than 5500 daily data to only 229, but with a higher degree of significance for monetary policies actions.

EVENT DAYS – 1988-2019				
Dependent Variable	**d_ytm_1**	**d_ytm_3**	**d_ytm_6**	**d_ytm_12**
Intercept	-0.0171*** (0.004)	- 0.009** (0.004)	-0.0143*** (0.004)	-0.0137*** (0.005)
R_un	0.1773*** (0.040)	0.1955*** (0.037)	0.1768*** (0.034)	0.1635*** (0.071)
R_e	0.1725***	0.1904***	0.1745***	0.1594***

	(0.038)	(0.036)	(0.033)	(0.069)
R^2	**0.239**	**0.293**	**0.268**	**0.166**

*Table 2 - OLS Regression with the delta-yield of various maturity Treasury Bills as dependent variables (d_ytm_x) over the entire sample of event days, intended as the FOMC meetings ending days (1988-2019). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

As for the correlation study, the focus on the Event Days only shows a sensible increase on the relevance of the regression under many aspects. Analysing firstly the Coefficient of Determination, there is a sensible increase in it for every security under analysis: from a 0.005 presented before, the average of the R2 moved up to 0.2 and above. This aspect shows that there is a greater significance in the specification of the study in this case, rather than what it was possible to see analysing the complete sample. This precise selection of the days in which the monetary policy takes place increase also the magnitude and the statistical significance for all the independent variables, and this aspect increase the significance of the study over the sample. The impact that a unitary change of both the two components is ten time higher during the ending day of the Federal Open Market Committee meeting than it is if analysed on a standard day; this increases the rational significance of the model, making it more worth to be analysed. A more important aspect is that coefficients estimated in this sample have a strong significance from a statistical point of view: independent variable p-values moved from a 0.8 (on average) achieved on the day-to-day analyses to values that are generally lower than the 1%.

In contrast to what it was possible to gather from the first table of the paragraph, shifting the focus on more specific dates increase the significance of the model, allowing to admit the existence of a relationship between the independent and the dependent variables, and that such relationship can produce statistically significant consistent coefficients.

The last analysis that can be done is to take into account how the model performs analysing data in crises times against the reminder part of the sample until 1994.

When referring to crises times the sample taken into account goes from 2008 on, from the beginning of the zero lower bound that American monetary authorities set as limit for the Fed Fund Rate up to the economic recovery after 2015. Financial markets, and the economy as a whole, modified their behaviours during the years between 2008 and 2015; furthermore as the target rate reached its lowest possible level, with other monetary expansionary policies run by the Federal Reserve, it was difficult for the market to imagine a change in the Target of the Fed Fund Rate. The following two tables will thereby provide a synthesis of the results of a linear regression over these samples presented above: the "normal times" tables refers to the 63 FOMC meeting ending dates between 1994 and 2008, while the next one to the event days occurred after 2008.

Normal Times - EVENT DAYS – 1994-2008				
Dependent Variable	**d_ytm_1**	**d_ytm_3**	**d_ytm_6**	**d_ytm_12**
Intercept	-0.0182*** (0.007)	-0.0098* (0.004)	-0.0120* (0.007)	-0.0144*** (0.005)
R_un	0.1221** (0.058)	0.2337*** (0.05)	0.129*** (0.048)	0.1835*** (0.051)
R_e	0.1190** (0.056)	0.2283*** (0.048)	0.1289*** (0.046)	0.1795*** (0.05)
R^2	**0.139**	**0.361**	**0.196**	**0.225**

*Table 3 - OLS Regression with the delta-yield of various maturity Treasury Bills as dependent variables (d_ytm_x) over normal times' event days, intended as the FOMC meetings ending dates in the interval (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

Crisis Times - EVENT DAYS – 2008-2019				
Dependent Variable	**d_ytm_1**	**d_ytm_3**	**d_ytm_6**	**d_ytm_12**

Intercept	- 0.0014 (0.003)	- 0.0051* (0.004)	- 0.0041* * (0.007)	- 0.0032 (0.003)
R_un	0.3748* ** (0.122)	0.3913* ** (0.059)	0.3302* ** (0.051)	0.2046 (0.448)
R_e	-0.0144 (0.069)	-0.0007 (0.066)	0.011 (0.012)	-0.0178 (0.057)
R^2	**0.534**	**0.534**	**0.664**	**0.23**

*Table 4 - OLS Regression with the delta-yield of various maturity Treasury Bills as dependent variables (d_ytm_x) over normal times' event days, intended as the FOMC meetings ending dates in the interval (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

The two tables, if compared resent unexpected results. The coefficient of determination achieved in crisis times is much higher than the one presented by the OLS regression on the event days of the "normal times" sample. Specifically, the regression on shorter maturity treasuries seems to present an enhanced significance over modern times, while over a yearly time horizon the R2 get back to the previous levels. A second aspect that should be noticed is the inversion in the coefficient sign for what concern the "expected component" of the monetary change; although, this inversion is coupled with a substantial reduction in the statistical significance of the coefficients related to such independent variable, making the estimated value not so reliable. On the other hand, the coefficients related to the Run independent variable are statistically significant at the 1% level for both the intervals on which the linear regression run. Is the unexpected component the driver of the increment in the R2 statistics, as if tried into a univariate OLS setup the results for one to six month T-Bills would be similar to the one achieved in the above table. The impact of the unexpected change in monetary policies has been sensibly more relevant in these last years, with a coefficient increase of the 30% circa.

The regression presented in this section are specifically aimed in understanding the ability of the model to gauge the movements in the Delta-YTM for bonds at different maturities, how it performed over specific intervals, and how its single components modified their behaviour.

For every regression the F-statistic has been checked, and so the associated p-value: almost all the regressions presented in the previous tables show significance at the 1% level. The only regressions that present p-values associated to the F-Statistic are the one over the entire amount of daily observations (table "COMPLETE SAMPLE – 1988-2019"), making then those results not particularly reliable.

Anyway, from the results presented above we can confirm that there exists a relevant relationship between US zero-coupon Treasury Bills and fluctuations in the rates of futures on the Fed Fund Rate. We can anyway confirm that such relationship produce significant results especially on the last days of the Federal Open Market Committee Meetings, and that the independent variable related to the "unexpected component of the monetary policy change" had an increasing relevance in last years. Anyway, it should be noticed that the component that proxies markets' expectations lost its power in recent times, with results showing that it is no more relevant in predicting changes in yields.

The Delta-yield analysis can give an approximate measure of the relationship between the independent variables and returns, indeed Tuckman and Serrat (2012) [6]proposed a pragmatic approximation for the calculation of daily returns of fixed income securities which takes into account not only the difference in prices, but even the first and second moments of the price (Duration and Convexity).

$$R_t = (1 + y_{t-1})^{\frac{1}{365}} - 1 - D_t \times (y_t - y_{t-1}) + \frac{C_t}{2} \times (y_t - y_{t-1})$$

[6] Bruce Tuckman, Angel Serrat, **"Fixed income securities : tools for today's markets"**, Wiley Finance, 2012

Where:

- R_t: daily return in day t;
- y_t: annual yield to maturity at day t;
- D_t: duration on day t;
- C_t: convexity on day t.

With Duration and Convexity that are calculated respectively as:

$$D_t = \frac{\partial P_t}{\partial y}$$

$$C_t = \frac{\partial^2 P_t}{\partial y^2}$$

Both, convexity and duration are calculated as functions of the annual yield-to-maturity, but both account for the value of the remaining maturity for the bond. Indeed, these two measures are calculated as the first and the second derivative of the price of a bond. The two measures give hints on prices behaviours and allows an estimation of the return levels in a more precise way than simply a difference in yields. The coefficient associated to the (dollar) duration measures the rate of change in prices according to a unitary variation in yields, giving then the sensitivity of the price as a response to the modification in the yields levels. On the other hand, the convexity represents the second derivative of the price equation, giving then the measure on how the duration level changes in response to a modification in yields. This relation is then a measure of the curvature in the relationship that exists between bond interest rates and their prices, with a higher convexity implying a more "convex" curve defining their relation, and so a higher sensitivity of the bond prices for a change in yields. The main difference is that, while duration assumes the existence of a linear relationship between bond rates and prices, convexity allows this connection to take a slope degree in its shape, allowing a better estimation when there are consistent changes in interest rates from one day to another.

Treasury Bills: Return analysis

The last aspect to be considered in the analysis of the behaviour of zero return bonds is the estimate on their daily returns and how they behave in correspondence of the fluctuations in monetary policies.

In order to calculate the daily returns over Treasury Bills the price of the securities has been calculated bringing back the YTM from an annual yield to a daily extent, considering as the time horizon of the year 360 days. Indeed, the yearly Yield-To-Maturity is calculated over such number of days rather than the entire 365 sample. Once obtained the price of the bond, the formula used to achieve the level of daily return is the standard one:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

Where P represents the daily price of the security. For Zero-Coupon Treasury Bills the price is calculated as:

$$P_t = FV - (M_t \times y_t \times 360^{-1})$$

With M_t representing the days to maturity.

In this section, the analysis will follow a setup similar to the one used for the difference in yields, and therefore estimating the linear connection existing between returns on bonds and the independent variables over the different samples already presented above. Again before starting with the regression procedures, data on returns over the various set are analysed through an Augmented Dickey-Fuller Test as to ensure that the distribution of the variables (and at this stage particularly the dependent ones) are stationary, allowing correct estimates.

The first Ordinary Least Squares Regression takes into account the entire amount of the daily observations, going from the last months of 1988 up to 2019. In the previous section this kind of analysis did not gave consistent results, although the establishment of a day-to-day relation is a desirable outcome, justifying a second test over this specific sample.

COMPLETE SAMPLE – 1988-2019				
Dependent Variable	**R_1**	**R_3**	**R_6**	**R_12**
Intercept	0.00* (0.001)	0.000* (0.000)	0.00** (0.000)	0.001** (0.001)
R_un	- 0.0002 (0.001)	- 0.0007 (0.0003)	- 0.0008 (0.004)	- 0.0022 (0.011)
R_e	- 0.0002 (0.001)	- 0.0007 (0.013)	- 0.0008 (0.004)	- 0.0024 (0.011)
R^2	**0.004**	**0.005**	**0.006**	**0.004**
F-Statistic	**0.171**	**0.03136**	**3.344**	**2.958**
Prob (F-Statistic)	**0.843**	**0.969**	**0.035**	**0.052**

*Table 5 - OLS Regression with the daily returns of various maturity Treasury Bills as dependent variables (R_x) over the complete sample of daily observations (1988 - 2019). Asterisks as confidence levels: * 10%, ** 5%*

Even analysing data on returns, a regression performed over the entire sample do not provide consistent results. There are although two takeout from this kind of analysis, an increase in the coefficient of determination over longer maturity bonds, that anyway remains very low, and an inversion in signs for the coefficients associated to the various independent variables in the regression, which although are low in magnitude and in statistical significance. A last aspect of differentiation between returns over short time maturities and longer expiration Treasuries is the F-statistic and the associated p-value. Indeed, if short times do not shows any significance under this aspect, increasing the time horizon of the bond the p-value associated to the F-Statistic shows an enhanced significance profile.

The reason for the inversion in coefficients' sign is a direct consequence of the impact that yields-to-maturity have over a bond price: since YTM represents the discount factor of the bond payments (in this specific case the Face Value redemption), an increase in its value would bring down the price level. As it was seen in the section dedicated to the regressions on yield variation, the positive relation that links independent variables with such term implies that for an increase in Fed Fund Futures rate values there is an associated increase in bond yields, and therefore a reduction in the new price level.

It is not possible to arrive at conclusive considerations while taking into account data on the totality of the observations, but it is possible to see indeed a pattern from a high scope view. Indeed, if returns on shorter maturity bonds seems not to be affected by an everyday change in Fed Fund Futures and in their delta with the effective change in target rate, increasing the investment horizon of such instrument the impact seems to increase. On one side, this effect may be a consequence of the persistence that such effects inject in the yield behaviour, while on the other it may highlight a lack in the responsiveness of the data to effects that take quite a long time in expressing in the real economy. In case that the answer is the latter, the following analyses would produce similar results since they focus on the responsiveness of these values during "event days".

As anticipated, the next regression will focus on all the ending dates of the Federal Open Market Committee meetings, together with the changing days occurred before 1994, as to measure the impact that changes on monetary policies had on the market on the exact days when they have been published by the authorities, and received by the operators. The "Event Days" sample measures around 200 observations of relevant days, and it would be useful not only in determining if the change in monetary policies effectively impact bonds' cumulative returns, but even to determine how this impact is received by securities with different time horizons, and how they rapidly adjust. The following table summarizes the result of this kind of analysis on such sample, presenting the estimated coefficients, with related significance and standard errors, and the coefficient of determination obtained by the regression on a specific security.

EVENT DAYS – 1988-2019				
Dependent Variable	**R_1**	**R_3**	**R_6**	**R_12**
Intercept	0.00*** (0.004)	0.0002* (0.004)	0.0003*** (0.00)	0.0008* (0.001)
R_un	-0.0009*** (0.00)	-0.0038*** (0.001)	-0.0043*** (0.001)	-0.011** (0.004)
R_e	-0.0009*** (0.00)	-0.0037*** (0.001)	-0.0042*** (0.001)	-0.011** (0.004)
R^2	**0.133**	**0.204**	**0.172**	**0.092**
F-Statistic	**3.904**	**6.658**	**7.003**	**3.122**
Prob (F-Statistic)	**0.0218**	**0.0016**	**0.0011**	**0.0463**

*Table 6 - OLS Regression with the daily returns of various maturity Treasury Bills as dependent variables (R_x) over the complete sample of event days' observations. Specifically, event days are those of the Target Rate level disclosure(1988 - 2019). Asterisks as confidence levels: * 10%, ** 5%,*** 1%*

The regression data show a similar pattern to the one achieved on the sample containing overall the observations, but with an increased significance. Firstly, it is important consider the improvement in the statistical relevance of the study, which in this case present a p-value of the F-Statistic that is slightly above 2% for the 1-month Treasury Bill, and that declines increasing the investment horizon. This specific result seems consistent with previously just supposed in the total sample regression. Even the Determination Coefficient related to the various securities increases over time, never reaching the level obtained for the difference in yields, but reaching for the 6-months maturity T-Bills a degree similar to the previous one. The R^2 coefficient generally seems to increase up to such maturity (6 months), while then it seems to decrease in magnitude if analysed on a security with higher maturity. Nevertheless, an aspect that should be considered in the analysis is that the result on the yearly zero-coupon US Treasury is the one for which the p-value of the F-statistic is the lowest, and the coefficients are statistically significance with the small interval of confidence, suggesting a stronger performance of the model over it.

This estimation shows statistically significant estimated coefficients, which although do not have a great magnitude: given a unitary increase of the estimators, on average, the impact reflected on returns can be quantified into a pair of basis point. Even for this characteristic, to an increase in the time horizon of the bond investment there is an increase in the estimated coefficient, demonstrating that such impact is stronger over longer maturities, while it tend to be limited for data on the one-month Treasury Bill.

As already done for the difference in yields, the last analysis that will be performed over zero-coupon treasuries' returns is comparing the performance of the model for what concerns the ability of the model in explaining the behaviours of US Treasuries' returns over "normal" and "crisis" times. The second sample then will contain all the data registered when the lower bound of the target was zero or almost-null, and in which the majority of the years were affected by several other measures of monetary policies for which the independent variables do not account for. From the previous test, rationally the stronger results should be obtained in the "crisis sample", as the highest connection showed in the delta yield should thereby be reflected in returns, with although an opposite sign of the coefficient. For this time interval it should be expected a lower impact of the component of the change forecasted by the market. As before, the number of observations is distributed almost evenly between the two samples.

Normal Times - EVENT DAYS – 1994-2008				
Dependent Variable	**R_1**	**R_3**	**R_6**	**R_12**
Intercept	0.0001** (0.000)	0.0002* (0.000)	0.0004* (0.001)	0.0014*** (0.001)
R_un	-0.0009** (0.00)	-0.0059*** (0.001)	-0.0046*** (0.002)	-0.0184*** (0.011)
R_e	-0.0009** (0.00)	-0.0058*** (0.001)	-0.0046*** (0.002)	-0.018*** (0.01)
R^2	**0.138**	**0.361**	**0.196**	**0.225**
F-Statistic	**2.335**	**11.44**	**4.109**	**6.483**
Prob (F-Statistic)	**0.106**	**0.00**	**0.0213**	**0.00283**

*Table 7 - OLS Regression with the daily returns of various maturity Treasury Bills as dependent variables (R_x) over the sample of event days' observations that occurred over policy homogeneous times. Specifically, event days are those of the Target Rate level disclosure (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

Crisis Times - EVENT DAYS – 2008-2019				
Dependent Variable	**R_1**	**R_3**	**R_6**	**R_12**

Intercept	0.00 (0.00)	0.0001* (0.00)	0.0001** (0.001)	-0.0003 (0.002)
R_un	-0.0029*** (0.001)	-0.0099*** (0.002)	-0.0117*** (0.002)	-0.0205 (0.045)
R_e	0.00 (0.001)	0.00 (0.002)	- 0.0004 (0.00)	0.0018 (0.018)
R^2	**0.536**	**0.534**	**0.664**	**0.231**
F-Statistic	**4.716**	**22.16**	**33.08**	**0.1048**
Prob (F-Statistic)	**0.0122**	**0.00**	**0.00**	**0.901**

*Table 8 - OLS Regression with the daily returns of various maturity Treasury Bills as dependent variables (R_x) over the sample of event days' observations that occurred over the years following the Financial Crisis. Specifically, event days are those of the Target Rate level disclosure (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

From the two tables it is possible to see again an inversion in the tendency between years with a normal floating of the fed fund rate and the crisis ones, where a strong backstop to it has been applied. Looking at the F-Statistic p-values, the relevance of the model over the last years has been increasing, and this is reflected even in higher levels of R2 and in a greater magnitude in estimated coefficients. Another strong difference stands in the statistical significance of the coefficients related to the expected component of the monetary change: if it has been an effective measure in gauging movements before the advent of the zero lower bound, in those years it provides a limited utility in determining the movements of Bond Returns. Although, on the coefficient side has been registered a sensible increase in the ones related to the unexpected component: in the first regression, which analyses the years before 2008, the coefficients related to Run were quite low, with a unitary increase in the variable moving returns of 1-2 basis points. In the “crisis times” regression, such effect between the unexpected component and bond returns increased up to 20 business points per unitary change, which can be considered as an acceptable impact.

The various Linear Regressions over zero-coupon bonds returns confirmed the results achieved in the Delta-Yield section. The main confirm are: that the relationship between the independent variables used in the model and the Treasury market exists, that such relationship is stronger in those days when a change in the target is more likely to occur, and that the interaction between the independent variables and the market experienced a change in these last years. As structural for the analysis and for the consequent implementation into a trading strategy, it should also be noticed that the highest estimated coefficients are usually linked to longer maturity bonds.

Treasuries: notes and bonds

If the previous section was about Treasury Bills with maturity shorter than one year, the focus of this chapter are about those US Government Bonds that have longer maturity and that pays coupon over the year. The securities taken into account at this stage of the analysis are then two, five and ten years Treasury Notes, and thirty-years Treasury Bonds.

This kind of security have in common many aspects with the T-Bills presented before: they are considered risk-free securities, given the reliability of their issuer, they are a benchmark for their when they have to be compared with other debt securities, and they are liquid, given the great extent of their secondary market. Often US Treasuries represent the main choice as Risk Free Investment for a broad range of investors, and this is the main guarantee for the existence of an opportunity to trade them freely.

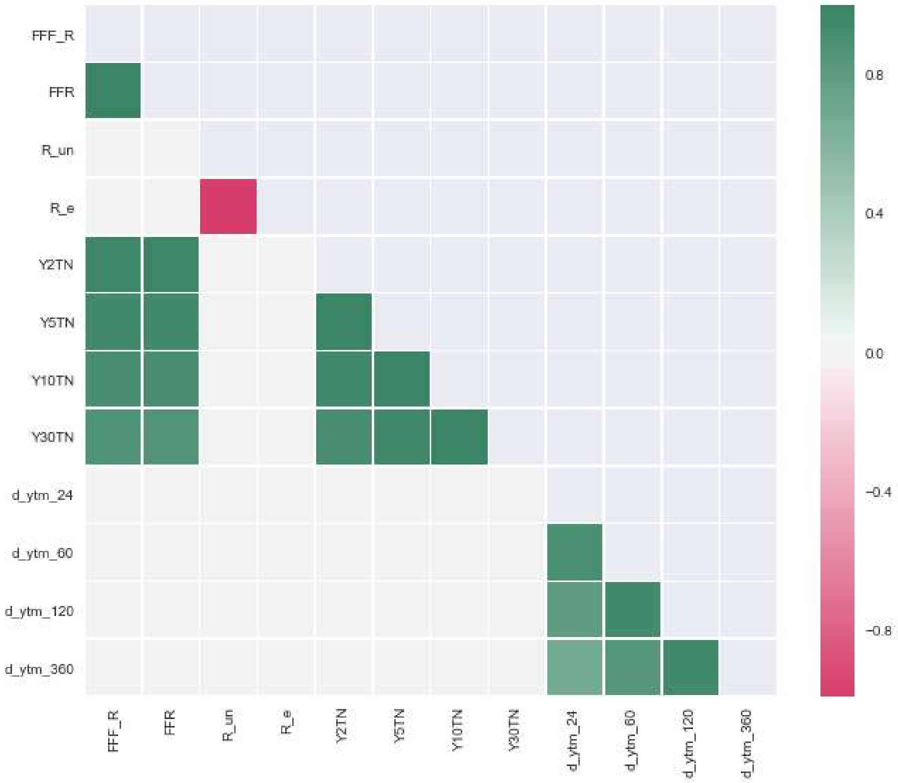
The key aspect that separates notes and bonds from bills is not only the longer maturity, but also even the coupon payment that occurs every six months (semi-annual coupon). As it will be better explained in the dedicated section the payment of a coupon will affect the formula for the return calculation, as having an impact on prices would require some adjustments even on the calculation of the duration and, consequently, of the convexity.

As it was for Bills, the analysis on Bonds and Notes would follow several different steps in order to provide an exhaustive outlook of the relationship between the securities and the component of the monetary change. Explicitly, starting from an overview of the correlation coefficients governing the relationship, the analysis will pass further to a Linear Regression over the difference in Yields experienced by such securities on a daily basis. In the end, the last section will focus on to the calculation of returns and the performance of an OLS regression of the independent variables R_{un} and R_e as to understand at which extent they affect bonds' returns.

Treasury Notes and Bonds: Correlation Analysis

Following the same rationale used for the analysis on short term Treasury Bills, the first step taken into account as to structure the analysis of Long Term Bonds is seeking if there is a correlation between the independent variables and the metric of interest for the study.

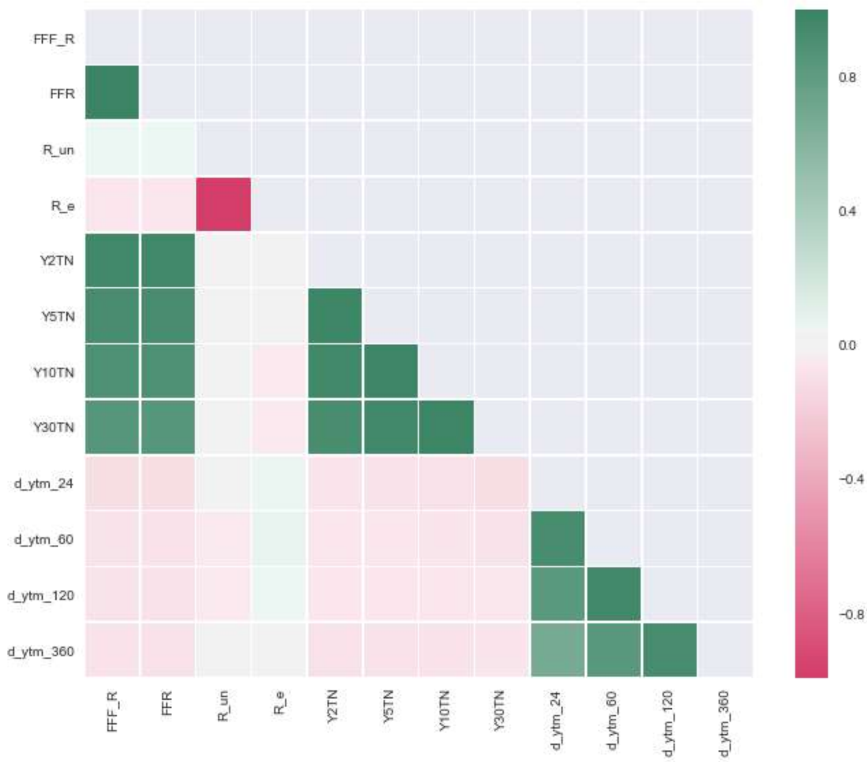
The first sample taken into account is the one formed by the entire amount of daily observations between 1988 and 2019. Again, it is rational to consider that among this wide sample the relationship should not be significant, although in the previous correlation test the unexpected change in the monetary policies increased together with the maturity of the analysed securities.



Graph 5 - Correlation Heatmap between delta-yields and independent variables over the entire sample of observations (1988-2019)

In the graph the variables denominated "d_ytm_x" represent the difference in YTM of treasury securities with maturity equal to "x" months. Even if the relationship between the Fed Fund Rate (FFR in the graph) and the Rate of the Futures on it (FFF_R) show high positive correlation coefficients with Treasury Notes and Bonds' rates, the variable of interests do not show any significant results. The result achieved and presented in the plot above is in contrast with the hypothesis that the connection between the estimated independent variables and the difference in yields is stronger at the increase of Treasury maturity even on a daily basis.

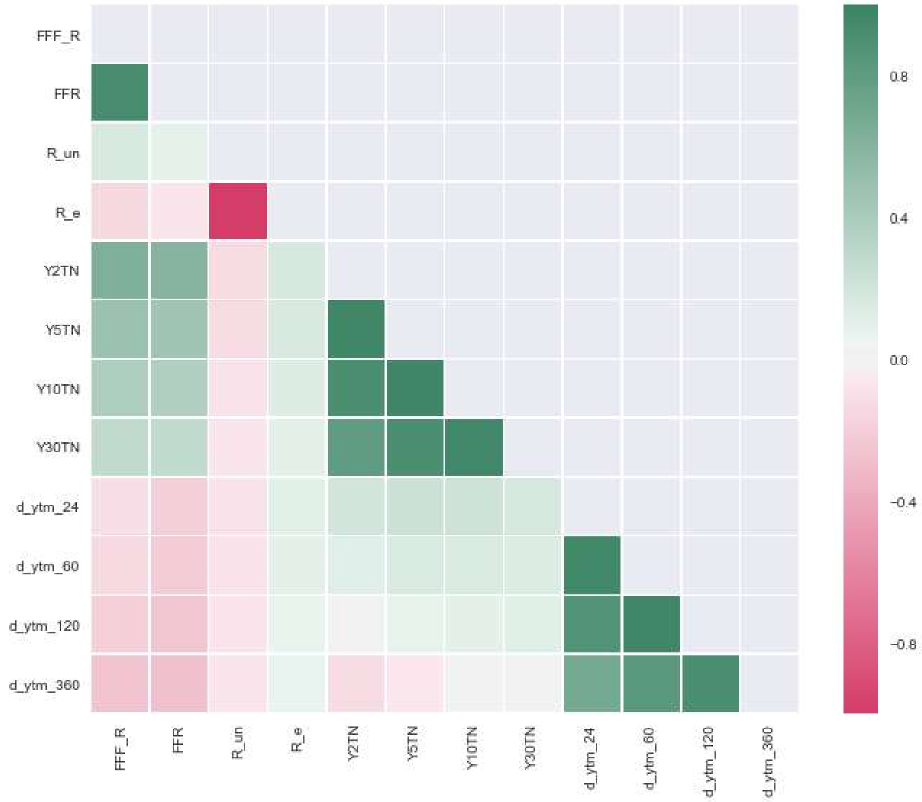
Even if the graph above do not seem to show any relationship between the variables that should be included in the model, the strong connection existing between the components of such variables suggest that there is again the opportunity to foster the result by considering timing aspect. In particular, following a similar pattern as did before, the next step of the analysis is the focus on just the Federal Open Market Committee meetings' ending day for the years after 1994, while for previous years observation the "event" is connected with the day after. This distinction is made as to effectively gauge FOMC announcements dates and with changes notification to the market.



Graph 6 - Correlation Heatmap between delta-yields and independent variables over the entire sample of event days. Specifically, are considered event days all those in which a disclosure of the change or the maintenance of the Fed Fund Rate Target occurred (1988-2019)

Again, focusing only on event days the graph starts to show the first signs of a relationship among the variable of interest. Even if the correlation coefficients are still small, and then not so significant, their presence suggest the focus on timing seems again to be one of the main way to enhance the catching of a connection in the model. Conversely, to what showed by the heatmap on the same observation sample for Treasury Bills, in this case is the expected component having a slightly positive correlation with the change in yields, while the unexpected part of the change shows a slightly negative coefficient. The focus on event days boosts results, suggesting that the approach used before could work for bonds as it did for bills, but the results provided cannot be considered conclusive, as the limited magnitude implies a low significance. Further slicing will be useful in determining if it is possible to achieve more consistent results, and to justify the run of an OLS regression analysis on longer maturity treasuries' rates and returns.

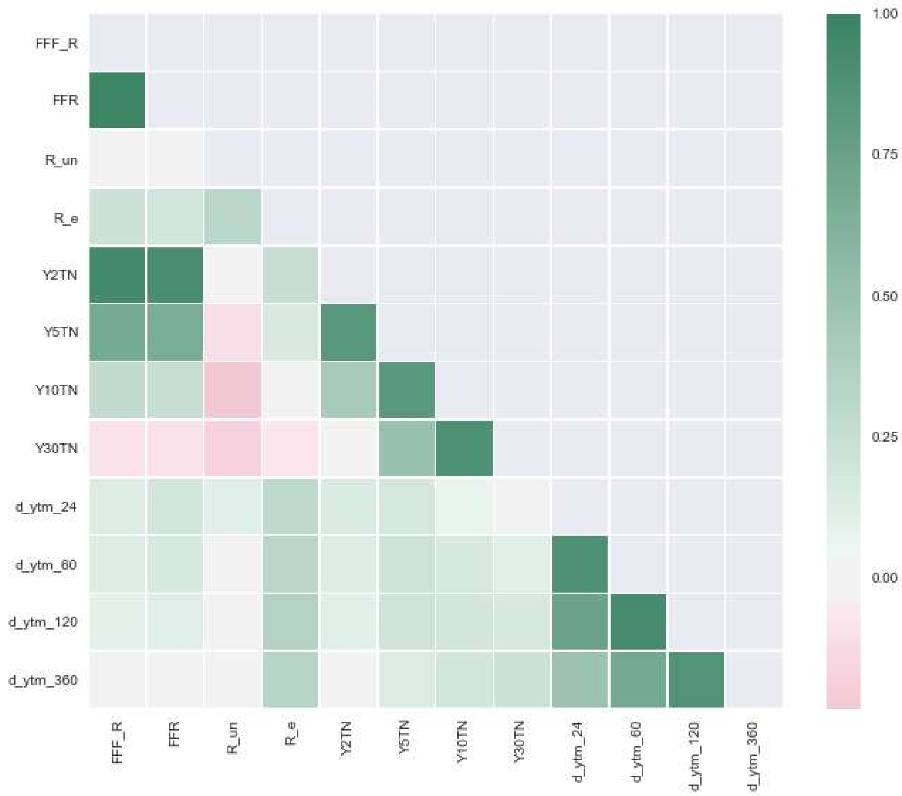
The next two graphs will be the consequence of a slicing in the sample used to produce the previous heatmap. Specifically the first slicing is aimed to allow the analysis of the relationship between the variable of interest on the FOMC meeting dates from 1994 to 2008. The sample gives highlight the aspects that can be related to times in which the behaviour of markets relatively monetary choices can be considered "normal", as there is no evidence of a strange behaviour in monetary choices, and the approach used by monetary authorities to employ their regulatory power follows standard methodologies and instruments.



Graph 7 - Correlation Heatmap between delta-yields and independent variables over the entire sample of event days that have an homogeneous disclosure policy, and were not affected by the 2008-2014 financial crisis. Specifically, are considered event days all those in which a disclosure of the change or the maintenance of the Fed Fund Rate Target occurred (1994-2008)

As in the previous sample, the slicing allows a fostering in the achieved results by the previous analysis, and this can be a consequence of the exclusion from the considered sample or of older data, or of those related to the years of the financial crisis and the zero lower bound in the Fed Fund Rate Target. Even if the correlation among the variables of interest is increased, the magnitude still remains not so significant, and decreases for securities with longer maturity. Another aspect that should be noticed, and that represent a major difference from previous analysis is the sign of the correlation coefficients. Notes and Bonds show a different relation compared with results obtained performing the same analysis on Bills, although the low dimension of those coefficients do not make them relevant; the opposite sign in correlation between independent variables is a normal consequence of their construction. On a higher scale, there is a low magnitude in the correlation coefficients achieved by the change in yield of every long-term investment analysed with the model independent variables if compared with Treasury Bills.

Again, the last aspect on which the analysis should focus is the joint behaviour between the variables in the model during the last years. Specifically, the attention will now be focused on the almost 70 FOMC meetings occurred from 2008 to the first months of 2019, period in which for circa the 70% of the daily observations are characterized by the zero level in the inferior boundary of the target rate. As to remind previously achieved results, in the section dedicated to the correlation of T-bills with monetary changes this last sample showed an improvement (and partially a reversion) of the connection between the variables in the model.



Graph 8 - Correlation Heatmap between delta-yields and independent variables over the sample containing event days in the years of the financial crisis and subsequent ones. Specifically, are considered event days all those in which a disclosure of the change or the maintenance of the Fed Fund Rate Target occurred (2008 - 2019)

Even in analysing the correlation between long term Treasuries it is possible to see how the correlation coefficient linking them to the independent variables is modified when analysed over this time interval. The unexpected component of the monetary change is in this case slightly positively correlated with the change in yields, while the "expected" one strengthen its position reaching coefficient around 0.5. Furthermore, the correlation seems to fade out when the maturity increases, with the correlation that is still present for notes at 2 and 5 years, but even comparing their fundamental drivers, for the Treasuries with maturity of 10 and 30 years the correlation reaches extremely low levels, and it even reverts for this last time horizon.

The correlation analysis shows a reduction in the correlation of long term Treasuries independently from the slicing applied to the considered sample. As pointed out, another element of discrepancy with the results of short maturity bonds is the reversion of the main correlated component between the two independent variables in the model, with Re having an increasing importance over the unexpected one. These results will probably have a sensible impact on the Linear Regressions that will be run in the next paragraphs, method through which it will be possible to definitely assess if it exists a relationship between the variables in the model and to determine its strength and if it is possible to identify a pattern in their behaviours.

Treasury Notes and Bonds: Linear Regression on Delta Yield

The next step in the analysis is then the identification of the rules and the extent in the joint behaviour between the two component of the monetary change and the variation in yields presented by Treasuries with maturity of two, five, ten and thirty years. The test in the paragraph dedicated to Treasury Bills sowed the existence of such relationship for all kind of bills, with a slightly increase for ones having six and twelve months maturity. Quantifying this relationship even for securities having a longer horizons would give hints on the persistence of the monetary change effect and the changes that it triggers. It would be rational that even if this effect can spread across the entire set of maturity, after a certain amount of time of the investment the market could start to consider it partially irrelevant, as the single change would be likely diluted by various other change that will affect the general behaviour of the investment.

Following the usual setup of the study, the first sample considered in the analysis will be the one covering the entire amount of observations included in the sample, starting from the last months of 1988 and ending in the first weeks of 2019. As it is possible to imagine from the results achieved by the correlation analysis and by previous tests on shorter maturity bonds, the OLS Regression on the total sample do not likely provide strong results, but it will be possible through it to get the underlying long term connections that may exists among the variables of interest.

COMPLETE SAMPLE – 1988-2019				
Dependent Variable	**d_ytm_24**	**d_ytm_60**	**d_ytm_120**	**d_ytm_360**
Intercept	- 0.0012* (0.001)	- 0.0012 (0.001)	- 0.0012 (0.001)	- 0.0011 (0.001)
R_un	0.023 (0.081)	0.0149 (0.054)	0.0069 (0.029)	0.0041 (0.012)
R_e	0.0236 (0.081)	0.0154 (0.054)	0.0076 (0.029)	0.0048 (0.012)
R^2	**0.003**	**0.001**	**0.000**	**0.000**

*Table 9 - OLS Regression with the delta-yield of various maturity Treasury Notes and Bonds as dependent variables (d_ytm_x) over the entire sample of daily observations (1988-2019). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

As supposed, the analysis on the overall sample do not show any significant relationship among the variables, and even the p-value associated to the F-Statistic of every of the previous OLS Regression are high enough to let assume that this model is not suited in the analysis of an everyday linear relationship among the variables under analysis. Although going to compare the coefficient estimated in the model, only a few reach the extent of a basis point, while the others are even lower in magnitude, presenting then an extremely low relationship on an overall basis. The inability of the model on catching the everyday relationship imply a lack of significance in each coefficient associated to the independent variables. The last consideration that is possible to make over the regression is focusing on the coefficient of determination expressed by the various models: taking in to account the one produced by OLS regression over Bills is possible to see an inverse relationship between the obligation maturity and the R2 value.

The day-to-day analysis suffers of the already expressed problems of dilution of change effects and in the leak of relevance in the natural fluctuations that prices can experience in those days in which there is no announcement or sentiment of a policy change. Focusing then on all those days the monetary authorities had the power to change the shape of the Target of the Fed Fund Rate, the change of the focus to an event study approach aimed to determine if even longer maturity fixed incomes are affected by this kind of choices. The first sample taken into account as to provide the high scope sight of this kind of analysis is then the overall amount of Federal Open Market Committee ending days from 1988 up to 2019, with the usual distinction for the dates before 1994. The next table will summarize the results of the OLS regressions on the delta yield over such sample.

EVENT DAYS – 1988-2019				
Dependent Variable	**d_ytm_24**	**d_ytm_60**	**d_ytm_120**	**d_ytm_360**
Intercept	- 0.002* (0.005)	0.00 (0.004)	0.0002 (0.005)	0.0001 (0.005)
R_un	0.0924*** (0.039)	0.0580 (0.053)	0.0263 (0.062)	0.0048 (0.053)
R_e	0.0923*** (0.002)	0.0594 (0.052)	0.0279 (0.06)	0.006 (0.051)
R^2	**0.055**	**0.023**	**0.00**	**0.00**

*Table 10 - OLS Regression with the daily returns of various maturity Treasury Notes and Bonds as dependent variables (R_x) over the complete sample of event days' observations. Specifically, event days are those of the Target Rate level disclosure(1988 - 2019). Asterisks as confidence levels: * 10%, ** 5%*

The linear regressions performed over the various treasuries with a view limited to the data recorded on event days show a reduction in the impact and the relevance of the model with the increase of the fixed incomes' maturity over the two years. The delta yield of the Treasury Note with maturity equal to 24 months is indeed the only one presenting an acceptable F-Statistic p-value (around 0.05), while for the ones with longer maturities its level sharply increase. Even for what concern the statistical significance of the coefficients, the table shows that only for the 2 years maturity note the estimated value can be considered an effective measure of the impact. On this entire sample of event days, consolidating this analysis with the results achieved on Treasury Bills is possible to see that the impact that the independent variable have on the US Government bond Delta-yield increases up to 2 years maturity. Five, ten and thirty years notes and bonds seem not to be highly responsive to monetary policies, especially on the exact day of the announcements, with the variation in the rates that seems not to be able explaining the fluctuation experienced by those securities' yields-to-maturity.

Indeed, for an investment horizon going above the short term, it would be unrealistic to expect a great reaction of the market to unexpected but quite recursive effects, even if the adjustment of their rate to shorter horizons securities would suggest the opposite.

As to have an idea on how the relationship between mid-long horizons Treasuries yields and the component of the monetary shocks changed over time, the next two tables will differentiate the events occurred before 2008, and the ones registered from the start of the financial crisis up to recent days. Previous OLS regressions showed an increment in the responsiveness to the unexpected component in recent days, especially on the 1 year horizon. The following tables would then highlight if previous results can be extend to the entire set of treasuries, and if in recent days the relevance of the unexpected component of the change could be a relevant measure of security fluctuations.

Normal Times - EVENT DAYS – 1994-2008				
Dependent Variable	**d_ytm_24**	**d_ytm_60**	**d_ytm_120**	**d_ytm_360**
Intercept	- 0.0052* (0.005)	-0.0039 (0.012)	-0.0052 (0.011)	-0.0043 (0.008)
R_un	0.1563** (0.065)	0.0774 (0.084)	0.014 (0.081)	- 0.0263 (0.054)
R_e	0.1548** (0.063)	0.0783 (0.082)	0.016 (0.079)	0.0212 (0.054)
R^2	**0.122**	**0.035**	**0.00**	**0.00**

*Table 11 - OLS Regression with the delta-yield of various maturity Treasury Notes and Bonds as dependent variables (d_ytm_x) over normal times' event days, intended as the FOMC meetings ending dates in the interval (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

Crisi Times - EVENT DAYS – 2008-2019				
Dependen t Variable	**d_ytm_ 24**	**d_ytm_ 60**	**d_ytm_1 20**	**d_ytm_3 60**
Intercept	0.069* (0.005)	0.009 (0.004)	0.0077 (0.009)	0.0085 (0.008)
R_un	0.0169 (0.346)	-0.0910 (0.492)	- 0.1172 (0.279)	- 0.1015* (0.07)
R_e	0.0673 (0.067)	0.1372 (0.152)	0.1654 (0.193)	0.1523 (0.151)
R^2	**0.088**	**0.10**	**0.139**	**0.11**

*Table 12 - OLS Regression with the delta-yield of various maturity Treasury Bills as dependent variables (d_ytm_x) over normal times' event days, intended as the FOMC meetings ending dates in the interval (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

The separation of the two samples shows results that are in contradiction to what achieved in previous regressions. The results of the linear regressions on 2 and 5 years treasury notes show higher correlation coefficient in "normal times" then what achieved by the studies on the sample 2008-2019. Even the statistical significance level of the coefficients related to those securities is slightly higher in the first table than what presented by the second one; furthermore, the impact that independent variables had on the yield difference in sensibly higher in normal times than what achieved during the "crisis sample". For what concerns ten and thirty years bond though, the results show an opposite tendency, with these security presenting an higher coefficient of determination in crisis times than the one showed in the normal times sample. Especially the 10-years treasury notes reached a 15% R2, with a unitary change in the independent variables that implies a 10-15 basis points change in the yield to maturity.

The analysis on longer term US Treasuries highlight the presence of some degree of significance just for what concern shorter term notes, while securities having a maturity longer than 5 years seems to be not so responsive to a change in the independent variables. Even the OLS Regressions showed on the differentiation of the sample based on the presence of zero lower bound in the Fed Fund Rate show an inverse behaviour with respect to securities with maturity within the year. This lower significance may be due to the relatively low shocks the market experience, and for crisis time, the higher influence of other variables and uncertainty related to those years. Even if the difference in yields-to-maturity is a structural component in the calculation of bonds' returns, the next section will be specifically focused on this last mentioned metric

Again the rationale of this paragraph is strictly related to the approximation of returns achievable through the difference in yield. Specifically, Treasury Notes ad Bonds are instruments that guarantees a semi-annual coupon payment, implying differences in the denominators when it is up to calculate a bond price, and then modifying the formulas linked to the determination of the security Duration and Convexity. The next formulas present the measurements for these longer horizon securities; as it will be possible to see, there is no much variation in the formula aimed to determine returns, while the more significant changes are registered by Duration and Convexity. Indeed, the structure of the payments implies a division in the yield used as discount factor, with although the related increase in its power coefficient.

$$R_t = (1 + y_{t-1})^{\frac{1}{365}} - 1 - D_t \times (y_t - y_{t-1}) + \frac{C_t}{2} \times (y_t - y_{t-1})^2$$

Again, the values presented in the three formula above are:

- R_t: daily return in day t;
- y_t: annual yield to maturity at day t;
- D_t: dollar duration on day t;
- C_t: convexity on day t

The reasons that suggest to consider even the behaviour of duration and convexity in the returns determination are the same presented for Treasury Bills, with their contribute that is structural in order to take into account the "risk" profile of the security analysed, or more specifically of the responsiveness that their price experience from a shock in yields. In this specific case, the two measures are not just function of the annual yield and of the remaining time to maturity of the securities, but even of the number of coupons the Treasury ensures over the year

Treasury Notes and Bonds: Return Analysis

This section will follow the same setup of the previous ones, showing the results of linear regressions over the returns of two, five, ten and thirty years' maturity bonds and notes, on observations going from the last months of 1988 up to 2019. The slicing in the sample will be the previous ones: the first study will focus on the totality of the daily observations in the sample, while the second one will be more focused in taking into account just the event days. The last slicing will be then addressed in analysing the differences arising between times of "normal" monetary behaviours and the ones during which the financial crisis affected the behaviour and the choices of the Federal Open Market Committee. This distinction will allow having an outlook of the behaviour and of the responsiveness of bonds' returns to shocks in the independent variables of the sample.

Starting from the first sample, with all days observations between 1988 and 2019, the following table will summarize the achieved results in terms of determination and responsiveness of returns to the model.

COMPLETE SAMPLE – 1988-2019

Dependent Variable	R_24	R_60	R_120	R_360
Intercept	0.0003* (0.00)	0.0006* (0.001)	0.0013 (0.000)	0.0052*** (0.001)
R_un	- 0.005 (0.017)	- 0.0077 (0.024)	- 0.0073 (0.031)	- 0.0012 (0.007)
R_e	- 0.0048 (0.017)	- 0.008 (0.028)	- 0.0081 (0.033)	- 0.0013 (0.007)
R^2	**0.002**	**0.001**	**0.000**	**0.000**
F-Statistic	**0.3235**	**0.2127**	**0.3725**	**0.498**
Prob(F-Statistic)	**0.724**	**0.808**	**0.689**	**0.6**

*Table 13 - OLS Regression with the daily returns of various maturity Treasury Notes and Bonds as dependent variables (R_x) over the complete sample of daily observations (1988 - 2019). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

As it was for the analysis on the yield variation, the day-to-day linear OLS model do not show great significance in the model, with the two independent variables showing a weak relationship with data on bonds' returns. The coefficient of determination, indeed, it is almost null for each security taken into account, with just for the two and the five years notes being few points above the zero. Similar problem of significance apply to the p-values not only of the estimated coefficients, but even to the ones linked to the F-statistic, whose are rarely below 0.7 and then being a proof of the inadequacy of the model in explaining everyday movements and returns. the results is similar to the ones achieved before, although suggests that, if there is a significance in the variables composing the model even under other samples and with more aimed slicing, it should be more relevant for shorter maturity securities, not reaching the 30 years extent of Treasury bonds. Comparing results on these securities' returns with the ones achieved by bills, suggest than that notes are the only one accounting for an effect, with coefficients that are similar to 6 and 12 months Treasury Bills.

In order to understand if there is some significance in the model when analysing these securities, the next sample will take into account the event days, on which a change occurred, or potentially could happen. Again, those days are the ones after the Federal Open Market Committee meetings' end for the years before 1994, while after February of that year the ones of the effective end, with this distinction originated by the policy of announcement putted in practice by the Committee in the years.

EVENT DAYS – 1988-2019				
Dependent Variable	**R_24**	**R_60**	**R_120**	**R_360**
Intercept	0.0004 (0.001)	0.00 (0.002)	0.00 (0.001)	- 0.0025 (0.017)
R_un	- 0.0186** (0.008)	- 0.0295 (0.028)	- 0.0263 (0.065)	- 0.0015 (0.184)
R_e	- 0.0186** (0.008)	- 0.0302 (0.027)	- 0.028 (0.062)	- 0.006 (0.179)
R^2	**0.055**	**0.022**	**0.007**	**0.001**
F-Statistic	**2.996**	**0.7543**	**0.1722**	**0.02898**
Prob(F-Statistic)	**0.0523**	**0.473**	**0.843**	**0.971**

*Table 14 - OLS Regression with the daily returns of various maturity Treasury Notes and Bonds as dependent variables (R_x) over the complete sample of event days' observations. Specifically, event days are those of the Target Rate level disclosure(1988 - 2019). Asterisks as confidence levels: * 10%, ** 5%,*** 1%*

Under this specific analysis is possible to see an increase in the determination power of the independent variables, with although still a small amount of determination ability by the model. Even analysing this specific sample, the only coefficient that are statistically significant at least at a 5% level are the ones related to the 2 years notes, with the other ones being relatively less significant and then reliable for the analysis. The Increase in the coefficient of determinations suggests, although, that the choice of focusing on event days only is functional in boosting the ability of the setup to explain variations; and this is potentially due to the considerations made before. The tables although shows higher magnitudes of the coefficients related to each one of the independent variables in the analysis, suggesting an higher responsiveness of returns to a shock in the expected and unexpected component of the change. As last component of the analysis, the p-values related to the level of the F-statistics remain high; this measure then implies a low significance of the model in studying the responsiveness of returns of such longer maturity bonds to the variations of the Fed Fund Rate used by monetary authorities to direction the behaviour of the economic and financial world.

The following two tables would then present the last two samples taken into account by the study, with a distinction between normal times and the one characterized by the financial crisis of 2008 and the following years. Normal times than ae those from 1994 to 2008, and are the one in which the policy of the Federal Reserve started to consolidate and the actions putted in practice by American Authorities followed a standard approach, allowing the market to set up their expectations in a consistent way over the day after of the meeting. Crisis times are, on the other hand, the ones in which the binding inferior level of the Target Rate stopped it to freely fluctuate, in which the target management was not more an instrument for monetary authorities, as already producing the maximum support to the economy, and in which other measures were triggered.

EVENT DAYS – 1994-2008				
Dependent Variable	**R_24**	**R_60**	**R_120**	**R_360**
Intercept	0.001 (0.002)	0.002 (0.012)	0.0057 (0.011)	0.0162*** (0.031)
R_un	- 0.0316*** (0.015)	- 0.0399 (0.043)	- 0.0153 (0.015)	0.082 (0.197)

R_e	- 0.0313*** (0.014)	- 0.0404 (0.042)	- 0.0173 (0.083)	0.0738 (0.191)
R^2	**0.122**	**0.035**	**0.00**	**0.00**
F-Statistic	**3.012**	**0.5122**	**0.0603**	**0.1056**
Prob(F-Statistic)	**0.053**	**0.61**	**0.94**	**0.9**

*Table 15 - OLS Regression with the daily returns of various maturity Treasury Bills as dependent variables (R_x) over the sample of event days' observations that occurred over policy homogeneous times. Specifically, event days are those of the Target Rate level disclosure (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

EVENT DAYS – 2008-2019				
Dependent Variable	**R_24**	**R_60**	**R_120**	**R_360**
Intercept	- 0.0014* (0.001)	- 0.0046 (0.005)	- 0.0079 (0.004)	- 0.0292 (0.028)
R_un	- 0.0034** (0.069)	0.047 (0.249)	0.1214 (0.065)	0.3455* (0.263)
R_e	- 0.0135 (0.014)	-0.0691 (0.077)	- 0.1693 (0.08)	- 0.5016 (0.502)
R^2	**0.088**	**0.105**	**0.138**	**0.122**
F-Statistic	**0.6415**	**0.4053**	**0.4258**	**1.462**
Prob(F-Statistic)	**0.527**	**0.668**	**0.656**	**0.239**

*Table 16 - OLS Regression with the daily returns of various maturity Treasury Bills as dependent variables (R_x) over the sample of event days' observations that occurred over the years following the Financial Crisis. Specifically, event days are those of the Target Rate level disclosure (1994-2008). Asterisks as confidence levels: * 10%, ** 5%, *** 1%*

The results of the two linear regression shows several interesting results and differences among the two samples that shows differences in the behaviours and the responsiveness of the different variables among the two samples considered.

The analysis indeed shows a much higher responsiveness of the observations registered during the crisis time than it was during normal ones, indeed the determination coefficients expressed by the OLS models in the second table are much higher than those presented in the first one, except for what concerns 2 years Treasury note. Even the coefficients estimated by the model have an higher magnitude for the years after the zero lower bound of the Fed Fund Rate if compared to the results of normal years, with a unitary change of the expected component that would trigger a sensible change in securities returns. The unexpected component, on the other hand, seems to trigger just a couple of basis points during crisis years, but in the opposite direction than the one suggested by the other independent variable, while an almost null effect in normal times. Anyway, the model do not seem to be efficient in offering a consistent estimation of the effects that a change in fed fund rate target has over longer Treasury bonds returns, with the confidence level of the estimations that rarely are above standard levels.

The various analyses performed over the observations related to notes and bonds suggest a reduction in the ability of the model in forecasting yields' movements. The daily effect of the fed fund rate than rarely impact longer securities, with the unexpected component losing its explanatory power over these longer horizons securities.

Stocks: Standard & Poor 500 Index.

The next step of the domestic securities analysis considers the behaviour of the U.S. Stock Market. Stocks are securities that represents a more direct link to the economy rather than the one offered by the Treasuries, representing the valuation of companies operating on the real economy; although the price formation of these securities is a process affected by a much larger number of components with respect to the one associated to Treasuries. Stock prices depends on several factors, which can be brought back to metrics in financial statements, to forecasts on the future behaviour of the company or to movement linked to the sector in which they operate, or even to other market dynamics. Nevertheless the Federal Reserve and the FOMC for it used to make decisions on the Fed Fund Rate addressed to sustain even the financial market, which although doesn't ever react as it would be expected, and that may have some deviation from rational expectations. The setup of the study should highlight the differences in market reactions by separating the unexpected component of the change from the one that could be considered as expected. Given the higher volatility of the stock market with respect to the Treasuries' one, even the timing of the expected component will be analysed, trying to understand the moment in which the price of the stocks starts to embody market expectations.

In this section, two different kind of studies are taken into account, the first one will be focused on stock returns, replicating the setup already used for bonds in the previous section, in order to establish a possible comparison on the ability of the two independent variables to explain changes in returns of different securities. The second one will focus on stock prices, which differently from bonds do not have a perfect linear relationship with the related returns, and are a more used variable in the technical analysis on time series of this kind of securities.

As already stated in the paragraph about timing, the Federal Open Market Committee used two different policies of disclosure about their decisions, with changes in the target occurring on the day of the meeting end just for the years going from 1994 on, while on previous years there was not an exact correspondence between the two events. The other feature is relative to the timing of the announcement, which was just subsequent the meeting since 1994, while previously was the opening price the one embodying the change in the Rate (and in the monetary perspective in the following months). According to this functional structure it is not possible to consider the FOMC meeting and the subsequent announcement as the only feature, but it implies a change even in the returns to be used in the regression, and this is even more true for what concerns stock analyses, given the volatility of the structure:

$$R_{bef1994} = \left(\frac{P_{op,t+1}}{P_{cl,t}} - 1\right)$$

$$R_{aft1994} = \left(\frac{P_{cl,t}}{P_{op,t}} - 1\right)$$

Where:

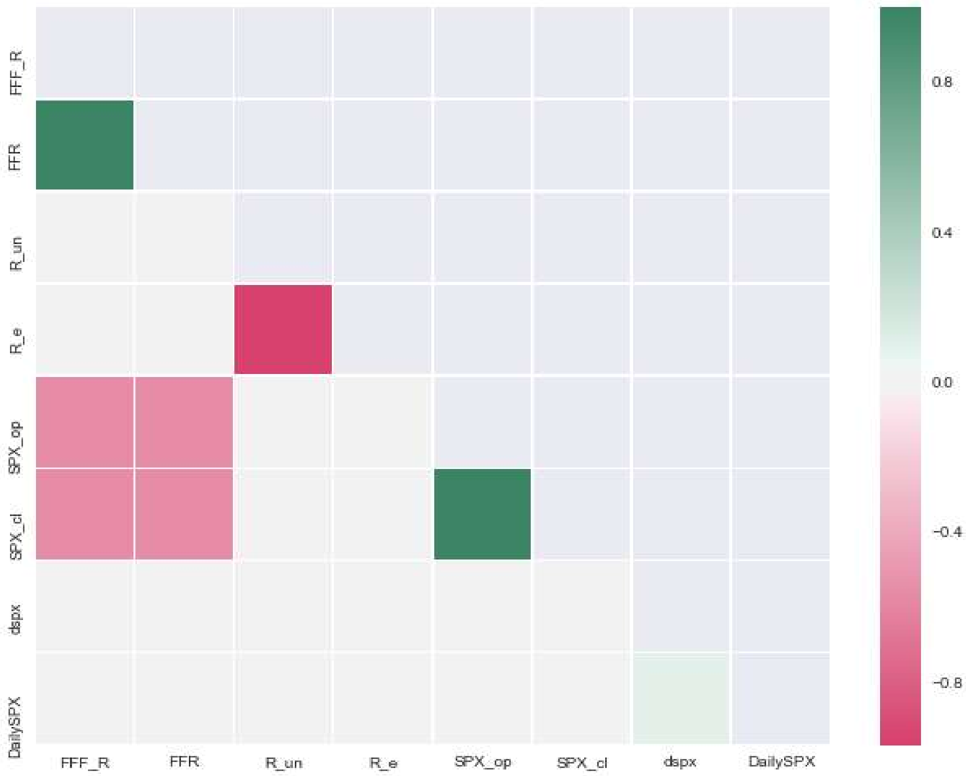
- $R_{bef1994}$: returns before 1994;
- $R_{aft1994}$: returns after 1994;
- P_{op}: opening price;
- P_{cl}: closing price;
- t: FOMC meeting day.

For what concerns the United States' stock market, the index taken into account is the S&P500, managed by the S&P Dow Jones Indices. This index is the one containing 500 American large-cap companies of a broad range of sectors, and its capitalization covers the great part of the American stock market (the 80% circa). The use of this specific index in the analysis is justified by the large breath of the companies that are included in its specification, with its quarterly update in weights and composition, and for its ability to be a proxy of the American Financial Market. Some drawbacks of its use are although linked to its composition and to the weights that are assigned on a market cap rationale, and that subsequently makes one-tenth of the company to account for more than a half of the overall Index Value. Even if there is the presence of these drawbacks, its importance as the broader American Index, is large and extensive usage by professionals, even as a benchmark, and its recognised ability to be a good proxy for the American stock market makes necessary to include it in the financial analysis. As for the Treasuries analysis, the observations taken in the analysis cover a time horizon of about 30 years, going from the end 1988 up to the first months of 2019 in daily data. As already announced before, for the regression on the stock market the returns taken into account are calculated on an open-to-close basis, trying to get the variation on a price closer to the Fed modification, with an overnight variation relatively to the 1988-1993, while a whole day one for the following years. The slicing of the sample will follow a similar rationale as the one used in the obligation/treasury market analysis: the study that will firstly focus on a regression on the overall sample in order to get a wide breath analysis of the forecast powers of the two independent variables on stock returns. Subsequently there will be a more punctual analysis on the days related to a change in the monetary policy, for passing in the end to the final observations slicing, with two distinct analysis on event days, one on normal times, while the other on crisis ones.

S&P 500: Correlation Analysis

Following a similar setup, the first analysis performed over this different security is a correlation analysis, as to identify if there is a relationship between the independent variables and stock returns, and to form a first idea on the strength of the binding between the variables in the model.

The first sample as always takes into account the entire sample of observations from 1988 up to 2019, accounting for more than 7500 daily observations over 30 years on a day-to-day basis.



Graph 9 - Correlation Heatmap between S&P Index returns and monetary change components (the model independent variables) over the entire sample of observations (1988-2019)

The heatmap shows the level of correlation existing among variables, with red squares showing negative correlation, while green ones are representative of a positive connection between variables. The darker the square, the higher linkage between the variable exists.

The variables presented in the graph are:

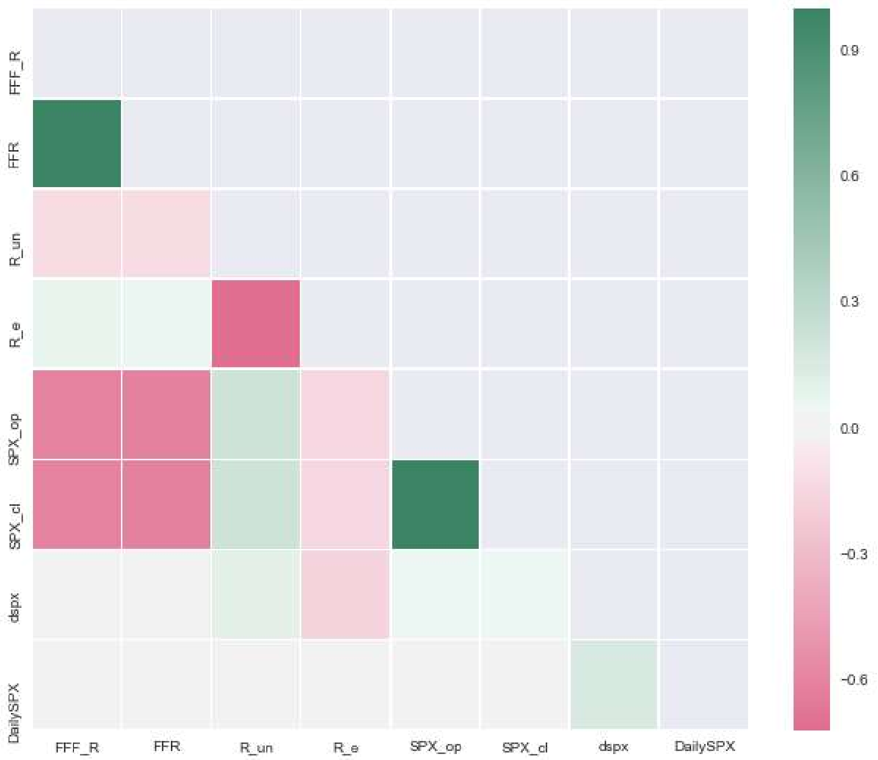
- FFF_R: Fed Fund Futures Rate;
- FFR: Fed Fund Rate;
- R_un: unexpected component of the Fed Fund Rate Target change;
- R_e: expected component of the Fed Fund Rate Target Change;

- SPX_op: S&P 500 index opening price;
- SPX_cl: S&P 500 index closing price;
- Dspx: S&P 500 open-to-close return;
- Daily_SPX: S&P 500 daily return.

The heatmap over the entire sample of observations do not seem to show many relevant results, with the majority of the squares being grey, and by that denoting a zero correlation coefficient in the intersection. It is significant although to register a slight negative coefficient among the rates of Fed Funds and Fed Funds Futures when correlated with index prices. This evidence suggests that the relationship between the variable of interest may arise in the subsequent slicing of the analysis, when the observations considered will be more relevant according to the setup created by monetary authorities in changing the desired level of the Fed Fund Rate Target.

The slight negative relationship indeed show that to a decrement of the fed fund rate, and so of the interval in which it is supposed to float, stock prices usually experience an increase in their level. This is consistent with the objective and the behaviour of Monetary Authorities when they give an address to the economy, but the effect do not seem to pass down to returns, remaining just at price level and then limiting the analytical power of the study.

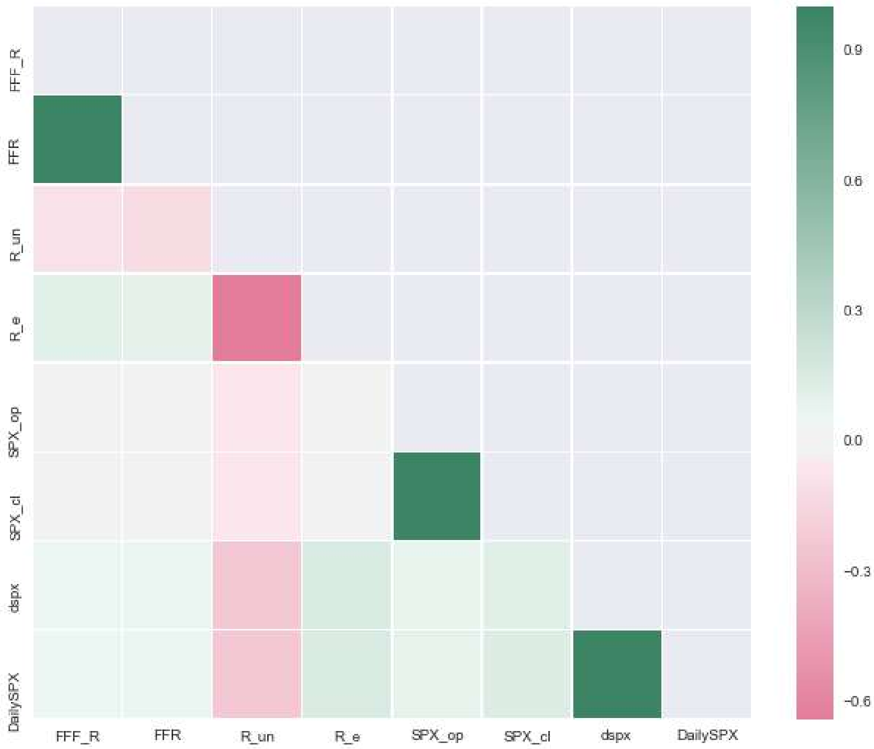
The next heatmap graphs will be focused on event days, and so those days on which a decision by the Federal Open Market Committee of the Federal Reserve is taken and disclosed to the public. As already said in the paragraph about timing, the “disclosure days” used to be the ones after the FOMC meeting until 1994, while for subsequent years they moved to the ending days of such summits, as to foster the impact they should immediately have over the market.



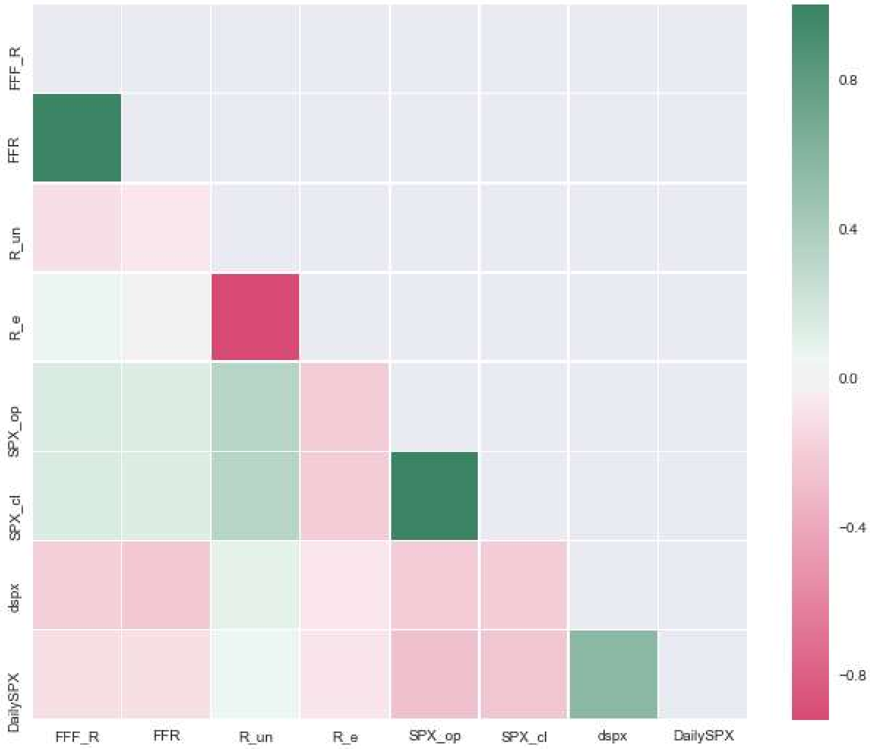
Graph 10 - Correlation Heatmap between stock index returns and independent variables over the entire sample of event days. Specifically, are considered event days all those in which a disclosure of the change or the maintenance of the Fed Fund Rate Target occurred (1988-2019)

Under this slicing in the sample, the graph show a correlation level among the variable of interest, with the expected component having a slight negative correlation with index prices and with the related returns, while the unexpected one having a positive correlation with prices, that becomes lower (always positive) linkage with open-to-close returns. Then focusing on event days, when the monetary policies are disclosed to the market, the significance of the study seems to increase, passing even to cumulative returns of stocks, as it was for Treasury bills in the dedicated paragraph. Although even if the scope of analysis is limited only to those observations registered on event days, the little magnitude presented by the correlation coefficient do not suggest enough significance as to determine the existence of a strong linkage among the variables in the study. Anyway since the expected and unexpected component seems to have a slightly higher correlation with stock prices, this aspect could suggest that a relationship exists, and that maybe an inversion in some behaviours of the variables as presented for fixed incomes may affect the results over returns.

The last step that should be made in this analysis as to align it to the ones made for Treasury securities is to distinguish the event days occurred during normal times, and the ones occurred during and after the crisis. This second sample, as already said in the paragraph dedicated to other securities, is strongly affected by an inferior boundary of the target rate that was zero, not allowing the Federal Reserve to move down the Fed Fund Rate, and representing the maximum boost to the economy offered by such instrument. The following two graphs will represent respectively, "normal times" intended as 1994-2008, and "crisis time" which captures the years of the crisis and the subsequent ones.



Graph 11 - Correlation Heatmap between delta-yields and independent variables over the entire sample of event days that have an homogeneous disclosure policy, and were not affected by the 2008-2014 financial crisis. Specifically, are considered event days all those in which a disclosure of the change or the maintenance of the Fed Fund Rate Target occurred (1994-2008)



Graph 12 - Correlation Heatmap between delta-yields and independent variables over the sample containing event days in the years of the financial crisis and subsequent ones. Specifically, are considered event days all those in which a disclosure of the change or the maintenance of the Fed Fund Rate Target occurred (2008 - 2019)

The second graph shows an increase of the correlation coefficients among the whole variables presented in the graph, with prices that seems to experience an increase in correlation with the two independent variables that will be used in the setup. An aspect that should be noticed is although the lack of correlation existing among returns and the components of the monetary change. This low correlation hold for both, daily and open-to-close returns, with no distinction among them for the sample about the years after 2008. On the other hand, analysing the observations registered during "normal times", the correlation of open-to-close returns with the independent variables of the model is slightly lower than the one presented by standard daily returns but the overall profile is indeed quite aligned between the two metrics.

The correlation analysis offers an outlook over the joint behaviour of the variables. The low correlation coefficients that characterize previous heatmap graphs in the intersections between the variables of interest do not suggest the achievement of high results in the next section, suggesting a low linkage between the regressors of the model and the variables they are aimed to estimate. Nevertheless, in each of the correlation tests is possible to see that there exist a clear linkage between Fed Fund Rate and the prices of the index, which although seem to reverse their behaviour in the last years of observations. Prices seem although to be even more sensitive to the independent variables variations than what showed by returns.

S&P 500: Return Analysis.

Even if previous studies do not suggest a strong linkage among stock returns and the components of the shock arising from a monetary change, in this section such relationship is analysed following a Linear Regression approach to the study. The numerical analysis will indeed give a more comprehensive and complete vision of the ability of Run and Re in explaining the movements of stocks' returns, allowing making hypothesis on the potentiality of the model in being a driver for the future formation of a trading strategy. As for Treasuries and for the Correlation Analysis, this section will start analysing the complete sample of observations of stocks' returns, moving then much in deeper to event days only, and then distinguishing between normal and crisis and post-crisis years. The variable taken into account during the regression of this section is the open-to-close return, which should be the first stationary series embodying the monetary shock. Furthermore, previous results obtained analysing the correlation coefficient support the idea that

The first sample than will contain the 7560 observation on returns registered from the last few months of 1988 up to the first weeks of 2019, being then quite comprehensive of observations and of fluctuations in the variable of interest. In previous analyses, this sample was never been particularly significant in terms of estimations, although it can be the source of some insight on the long lasting relationship between the component of the monetary change and the security. As already said in previous sections, this specific sample comprehend even those days on which the market knew it was almost impossible to experience a change in the Fed Fund Rate target, and so for which it was unlikely to see a fluctuation in returns caused by the Fed Fund Rate. The following table will then summarize the results achieved by the linear regression on open-to-close returns over such dataset.

Total Sample: 1988-2019				
N_obs	7560			
R2	0.001			
	coeff	**std. error**	**t**	**P>(t)**
Intercept	- 0.0003	0	-2.534	0.020
R_un	-0.0009	0.003	-0.297	0.766
R_e	-0.001	0.003	-0.297	0.769

Table 17 – OLS Analysis of the S&P 500 Index returns. This analysis is intended as a proxy of the responsiveness of the stock market to variations in the monetary policies announced by the FOMC. This analysis has been performed over the total amount of daily observations of the index returns and the independent variables from the last days of 1988 (1988-2019).

As expected the regression on the overall sample does not give many hints on how well the independent variables are able to forecast a change in the S&P500 Index, and then to the main financial stocks in the United States stock market. As already mentioned, the great number of factor that impact on the stocks' return imply a much lower ability of the regressors in achieving a good value of the coefficient of determination. The huge number of days in which a change in the Fed Fund Rate would not realistically occur lowers the consistency of the estimated coefficients. The coefficient of Determination presented by the previous table is extremely low, suggesting a lack in the ability of the independent variables in explaining the everyday change of open-to-close returns. Coefficients estimated by the model are not only extremely low, but also statistically insignificant, which makes the setup of the analysis useless in explaining the joint behaviour of the considered variables .

As for the treasury analysis, a more specific focus on the days of the FOMC meetings or on the days of a change would be a more interesting sample since the analysis is focused on forecasting changes in the monetary choices of the Central Bank. As for previous securities, the second sample contains a smaller number of observations but can be considered more relevant for what concern an analysis on the reactions to Central Banks' choices.

EVENT DAYS – 1988-2019				
N_obs	222			
R2	0.011			
	coeff	**std. error**	**t**	**P>(t)**
Intercept	0.001	0.001	1.723	0.085
R_un	-0.0147	0.02	-0.733	0.464
R_e	-0.0194	0.024	-0.795	0.427

Table 18 - OLS Analysis of the S&P 500 Index returns. This analysis is intended as a proxy of the responsiveness of the stock market to variations in the monetary policies announced by the FOMC. This analysis presents the results achieved when analysing the "Event Days". As for Bonds event days are does when the FOMC announces a change or the maintenance in the monetary policies. This table presents the results of the complete sample of event days (1988-2019).

In this case, the number of observations drastically drop from more than 7500 to only 220 circa. The linear regression presents an increase in the coefficient of determination, although it remains quite low as for previous analysis, slightly passing a level of 0.01. The almost null intercept is the only coefficient having a statistical significance, while other estimations linked to the components of the monetary change present high p-values, making then impossible to accept them as a good measure of the impact of monetary shocks. . As a difference from Treasury bonds, is possible to see an inversion in the sign of the coefficients, that although are quite low and, for what concern the independent variable signalling the expected effect, do not seem have a high degree of significance. From these results it do not seem to exist a strong relationship between stock returns and the Fed Fund Rate, or at least with the regressors used as proxy for the monetary policy effects at a daily horizon.

Two linear regressions should be made in order to have a comprehensive view of the effects that the independent variables have over S&P 500 index open-to-close returns. As it has been made in previous analyses, the last aspect to investigate is how the crisis times and the zero lower bound of the fed fund target affected the behaviour of markets when responding to changes expected or unexpected in monetary policies. The following tables will then present the performance of the model during “normal times” intended as the years before 2008, but after 1994, when the Federal Reserve modified its disclosure policy for what concerns variation in Fed Fund Target, and for the years after 2008. This kind of distinction has been extremely meaningful for Treasury Bills, for which the latter years showed an higher responsiveness to monetary shocks than what it was during previous ones.

Normal Times – 1994-2008	
N_obs	94
R2	0.056

	coeff	std. error	t	P>(t)
Intercept	0.0005	0.001	0.494	0.622
R_un	-0.0357	0.064	-0.557	0.578
R_e	-0.0024	0.119	-0.02	0.984

Table 19 - OLS Analysis of the S&P 500 Index returns. This analysis is intended as a proxy of the responsiveness of the stock market to variations in the monetary policies announced by the FOMC. This analysis presents the results achieved when analysing the "Event Days", does when the FOMC announces a change or the maintenance in the monetary policies. This table presents the results of the sample in "normal times", so from all those days that were not affected by the financial crisis and with an homogeneous disclosure policy of FOMC decisions. (1994-2008).

Crisis Times – 2008-2019				
N_obs	67			
R2	0.009			
	coeff	**std. error**	**t**	**P>(t)**
Intercept	0.0023	0.002	1.497	0.134
R_un	-0.027	0.18	-0.150	0.881
R_e	-0.0464	0.801	-0.058	0.954

Table 20 - OLS Analysis of the S&P 500 Index returns. This analysis is intended as a proxy of the responsiveness of the stock market to variations in the monetary policies announced by the FOMC. This analysis presents the results achieved when analysing the "Event Days", does when the FOMC announces a change or the maintenance in the monetary policies. This table presents the results of the sample in "crisis times" (2008-2019)

The distinction that for previously analysed securities highlighted some differences and some increase in significance, for the returns on the S&P do not seem to produce relevant output for the estimation. The coefficient of determination is low for both the datasets, with the one referring to "normal times" above the other one, but not reaching a satisfying level for the analysis. A second, but more important aspect that suggests the impossibility to set up conclusive result is the lack of statistical significance registered by the estimated coefficients, whose p-values are extremely high. This results do not allows to go further with the analysis of the impact that the expected and the unexpected components of monetary shocks have on stocks returns, the significance of the study indeed is almost null.

In conclusion is possible to say that the model which fitted quite well for Treasury Bills, and that maintained a sufficient level of significance even for bonds and notes, does not seem to fit well for stock returns analysis. The reasons behind such lack of significance in the model for this kind of securities may be researched in several different aspects, one of which may be an incorrect specification or assumption of the ability of the market in embodying the change in the exact day of disclosure, with the possibility of a previous forecast and then just some adjustments. Even the volatility of the security, whose prices tend to fluctuate much more than the ones of treasuries could be a reason of the lack in the ability of the model in determining returns fluctuations.

Trading Results: a simple long-short strategy

The results that were achieved in the Empirical Analysis paragraph suggest the existence of a relationship between Treasury rates and the behaviours of Federal Funds Rate, and especially Futures. This section of the paper is specifically addressed to the definition and the determination of a strategy aimed to exploit the relationship that rose from the Linear Regressions performed above, used them to backtest a trading strategy, and evaluating its performance over the years. Anyway, an aspect that as to be considered is the sample of observation on which to test the trading idea; specifically forming the estimations of the coefficients on the observations registered before will be tested over the last eleven years' daily returns.

As previous regressions were based on event days' movements of rates, the results were already reflecting the new levels achieved by both, dependent and independent variables. Forming a strategy over such relationship though requires the formation of some expectations over the change components of the monetary policies, as to allow the employment of the registered relationship effectively, and without falling into the standard temporal biases that may affect a backtesting procedure. Specifically, when testing an event driven trading strategy, assessing the timing in the inflow of new information necessary to form expectations results a crucial aspect as to be sure not to use market data that would result unavailable in case of a direct application of the strategy in the real world. The strategy that has been constructed and tested over the daily observations is a long-short dollar neutral strategy that could be employed in the rebalancing operations that affect a portfolio allocation over different maturity Risk Free Securities, in this case represented by one and six months zero-coupon Treasury Bills. The change in the allocation is driven by the components of the independent variables presented before as proxies of the expected and unexpected change in the Treasury market, on which movements are made the estimations, as to form the expectations and the trading signals.

In the next sections, are presented the two ideas used in the forecasting of the possible variations relative to the Target interval and the Futures' Rate of the Federal Fund Rate. Through the formation of such expectations is furthermore possible to apply a rebalancing strategy for a portfolio exposure to risk free securities, making it embodying the idea that longer maturity bonds are more responsive to changes. Given that, longer Treasury Bills are then better performing instruments when there is a reduction in the independent variables' levels, while shorter term ones would allow to offset the adverse effect produced by their increase (and particularly by the one produced from the increase in Futures rates).

Estimating Fed Funds Futures rate level

The unexpected component of the change is the one the presented the higher coefficients when analysing the impact that such estimated independent variables produced over the various samples of observation taken into account in the Empirical Analysis paragraph. The formula of such independent variable is:

$$\Delta r_{un} = \frac{dm}{(dm - t)} (f_t^1 - f_{t-1}^1)$$

It is clear that in order to structure a view over the future behaviour of such variables it is necessary to produce estimates over the level that the one-month Fed Funds Future rate will reach on the event day. This aspect is crucial in order to assess the sign of the trading information and in order to timely adjust the portfolio in order to benefit of the movements in the rates whose values are somehow related to such variable behaviour.

The standard setup to used by various studies in order to forecast the future level of Futures on the Fed Fund Rate is based on the revisions made by Orphanides, Athanasios and Wilcox (1997) [7]on the model proposed by Christiano, Eichenbaum and Evans (1997) [8]and already tested by Evans and Kuttner[9]. Such model is structured as a Vector Autoregressive calculation of the level of Fed Funds Futures, and it is based on the standard Fed Fund Rate plus series of other state variables. Specifically, among those state variables are included the logarithms of the level of the payroll employment statistic, the amount of reserves and the portion of the non-borrowed ones, the monetary supply, together with some metrics that are linked to the inflation level experienced by the Country. Evans and Kuttner assessed in testing it a lack of precision and a quite persistent noise, and this aspect could be amplified on a daily basis; indeed, many of the metrics included in the model are observed on a quarterly or (rarely) monthly basis, while the interest is in this case the daily variation.

In order to overcome the problems arising from this lack of precision and from the noise in observations, the alternative model used to forecast the rate of the Fed Funds Future is an Autoregressive Model. The expected rate achieved by the Future will be then the composition of its past values, whose would be observable at the time of the trade. To determine the correct number of lags to employ in the forecast through the AR model, it has been analysed the Partial Autocorrelation

[7] Orphanides, Athanasios and David W. Wilcox **The Opportunistic Approach to Disinflation,** Board of Governors of the Federal Reserve System, Finance and Economic Discussion Series, 1997

8 Lawrence J. Christiano, Martin Eichenbaum, Charles L. Evans, **Monetary Policy Shocks: What Have We Learned and to What End?,** NBER Working Paper No. 6400, 1997

9 Charles L. Evans, Kenneth N. Kuttner, **Can VARs describe monetary policy?**, 2000

Function of the Future Rate, through which it was possible to determine a good performance of a 5 lags estimation-

$$E_t[f_{t+1}^1] = \sum_{i=0}^{4} \hat{\beta}_i z_{t-i} = \sum_{i=0}^{4} \widehat{\beta_i}(f_{t-i}^1 - f_{t-i-1}^1)$$

Where E[]t represents the expectations achievable at time t, in this case over the one-month future rate, and $\hat{\beta}_i$. The term z represents the first differential of the Fed Fund Future rate with one-month horizon. Indeed, from the Augmented Dickey-Fuller Test over the series collecting the rates of the Futures it results the non-stationarity of the data used in the regression; taking the differential of a series is a standard method to bring the series to a stationarity layout. In order to check this method, it was run the testing over the differenced series, which indeed showed a stationary behaviour.

In order to give a correct estimation of the Beta coefficients, the previous specified regression has been performed over a wide sample of daily observations, going from December 1988 up to the last months of 2008, and then tested over the subsequent 10 years. This setup purpose is to state if through an autoregressive model is possible to achieve a consistent estimation of the Futures' level, avoiding the bias related to the time component of the estimation. The methodology achieves an overall good result, with the Mean Squared Error between model predictions and the observations in the testing sample having a quite low level (MSE = 0.02). The MSE indeed is a positive metrics incorporating not only the variance of the estimator, but even the biases that may affect it, value that when analysing an unbiased estimator tend to zero.

The following graph is intended as a mean of visual comparison between the actual observation of the Fed Funds Futures at one month horizon and the values predicted by the AR(5) model in the testing sample, and so in the years between the end of 2008 and the first couple of months of 2019.

Graph 13 – The Graph shows the comparison between actual and predicted values of the one-month Future over the Fed Fund Rate. The actual data of the Fed Fund Rate are in blue, while forecasted ones are in red. The instrument used to form the prediction is an Autoregressive model that takes into account the five previous lags of the variable. The train sample for the coefficient goes from 1989 to the last months of 2008. The plotted sample goes from mid-2008 on, using previously forecasted coefficients.

The red line is the one related to the prediction data, while the (almost invisible) blue one it is linked to the actual observations over the variable of interest. As it is possible to see from the figure, the two lines overlaps, suggesting that the estimation provided by the autoregressive model correctly forecasts the variable of interest of the study. The good fit of the model allows making a reasonable guess on the incoming level of the futures' rate, and then on the movements experienced by Run, the metric catching the unexpected component of the change in monetary policy decisions.

The Taylor Rule

As presented in the Empirical Analysis chapter, the effect of the change in monetary policies can be decomposed in two parts, one representing the portion of the change unexpected by the market, and the other the expected component. While the unexpected one can be estimated simply analysing the variation of the rate of futures on the Fed Fund Rate, the other one includes additional measures. Indeed, the Re independent variable is calculated by subtracting Run to the variation in the Target of the Fed Fund Rate set by Monetary Authorities, in this specific case represented by the Federal Reserve. If the instrument through which to determine a possible variation in the unexpected component may be represented by autoregressive model presented in the previous paragraph, estimating a possible change in the interval set as a target by the Federal Reserve requires several further assumptions.

In 1993, John Taylor [10]firstly proposed a numerical rule relating the target for Central Banks' short rates to the economic environment. The Taylor rule indeed was thought as a numerical benchmark for monetary authorities, with the intent to give a strict numerical rationale in the management of the Fed Fund Rate as to maximise its effect and to allow it to follow a precise rule in adapting to changing in the economic conditions. Specifically the rule states that:

$$r_t = \pi_t + \vartheta_1 y_t + \vartheta_2(\pi_t - \varphi) + \omega$$

Where:

- rt: the Fed Fund Rate at time t;

10John B. Taylor, **Discretion versus policy rules in practice**, Carnegie-Rochester Conference Series on Public Policy 39, pp 195-214, 1993

- yt: the percent output gap at time t;
- πt: the inflation at time t;
- θ1 and θ2: weights, usually equal to 0.5 both;
- ϕ: normal level of inflation;
- ω: natural rate of the Fed Fund Rate.

This rule prescribes that the FOMC should modify of θ1 percent for every one percent variation of the output gap, or of θ2 percent in for 1% variation of the inflation level with respect to a determined target ϕ. A simple mathematical formula although would not be realistically other than an ideal guideline to how the policy should be implemented and the path that it is supposed to take, as it simplifies the overall economic environment through two simple metrics, inflation and output gap. Although, even if the Taylor rule cannot be taken as a perfect representative of the Fed Fund Rate Behaviour, it can be useful in highlighting an approximation of the behaviour of the Fed Fund Rate Target.

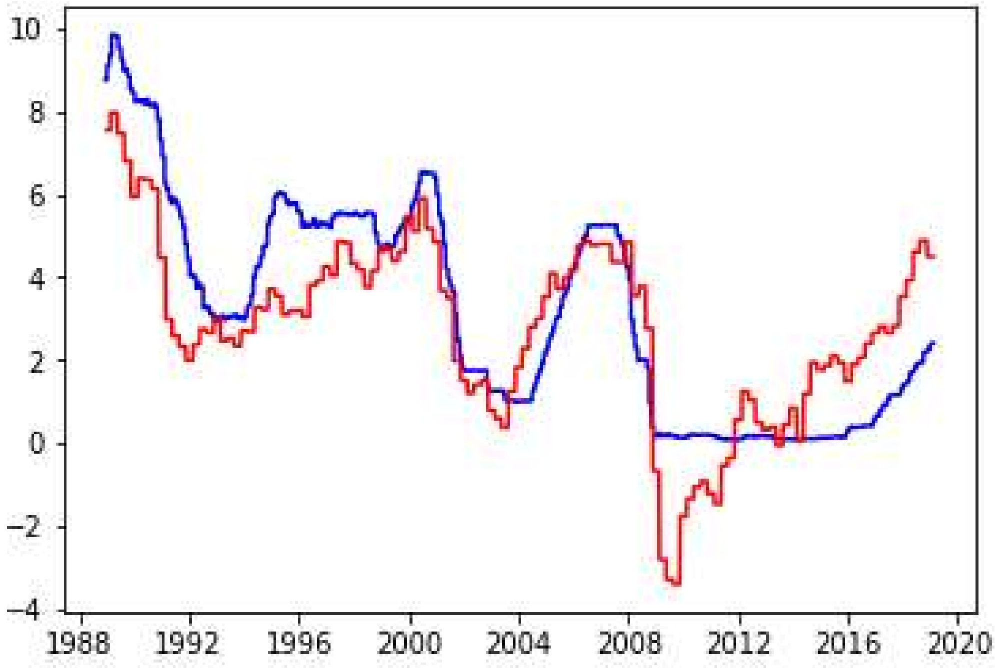
The rule is particularly respondent to the modifications of the measures used in determining the two measures, inflation and deviation from the output target, and by the definition of the coefficient levels. The standard Taylor rule uses as measure of inflation the Consumer Price Index, the target in the "deviation of GDP from a target level" (indicated by the letter y in the formula) is the output gap, intended as

$$y_t = \frac{\widetilde{GDP}_t - GDP_t}{\widetilde{GDP}_t} \times 100$$

Where $\widetilde{GDP}_t$ is the economy potential output. The last assumption of the standard formulation is that the weights used in the formula for the GDP deviation and the difference of the real inflation from a standard target (θ1 and θ2) are equal, with a level of 0.5 each.

Following the hints offered by Ben Bernanke [11] and the Federal Reserve Press Release12, the instrument used by Monetary Authorities to analyse the inflation is the "core Personal Consumption Expenditure", which it is slightly different from the broad used CPI (and usually lately available by market operators). Another modification to the standard setup is the increase up to 1.0 of the coefficient associated to the GDP component of the formula; this aspect has been presented for the first time in a paper by Taylor (1999) [13] subsequent to the one stating the rule, and then confirmed by a speech of Janet Yellen[14.] These modifications sensibly modifies the behaviour of the estimators of the Fed Fund Rate, making it nevertheless more consistent with the rationale followed by Monetary Authorities, and more linked to the Fed Fund Rate than it was the original setup. The next graph would thereby present the results achieved by the modification of the Taylor Rule modified using these assumptions

11 B. Bernanke, The Taylor Rule: a benchmark for monetary policy?, https://www.brookings.edu/blog/ben-bernanke/2015/04/28/the-taylor-rule-a-benchmark-for-monetary-policy/, 2015
12 Federal Reserve issues FOMC statement of longer-run goals and policy strategy, https://www.federalreserve.gov/newsevents/pressreleases/monetary20120125c.htm, 2012
13 J. Taylor, Monetary Policy Rules, University of Chicago Press, 1999
14 J. Yellen, The Economic Outlook and Monetary Policy, Speech at the Money Marketeers of New York University, New York, New York, 2012



Graph 14 –The Graph compares the actual level of the Federal Fud Rate with the one that can be calculated by the application of the "Rule" proposed by John Taylor. In Blue the actual monthly value, while in red the Taylor rule. The sample taken into account goes from 1988 up to 2019. Some modifications has been done to the standard formula proposed by Taylor, indeed the CPE core index has been used as inflation metric, and it has been done full weight to the output gap ratio, rather than half as hypnotized by Taylor calculations.

The blue line represents the actual level of the Fed Fund rate, while the red one the modified Taylor rule. As it is possible to see, the two graphs followed a similar behaviour from the last years of the 90s up to the incoming of the zero lower bound of the fed fund rate target. After 2008 the red line falls below zero, losing the similarity in the behaviour maintained up to that year until 2015-2016; after those years the modified Taylor-rule started again to have a behaviour coincident with the one of the Fed Fund Rate, maintaining although always an higher level than the one achieved by the actual rate it tries to forecast. This aspect has been pointed out even by John Taylor[15], which criticized monetary authorities over past years for their maintenance of a too easy policy during the financial crisis and for a too little increase of the rate in all the subsequent year.

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15 J. Taylor, **A Monetary Policy for the Future**, transcript from the IMF Conference "Rethinking Macro Policy III, Progress or Confusion?", 2015

Even if the two rates are not exactly coincident, their seem to have a quite joint behaviour over the majority of the years, especially for those in which the Fed Fund Rate is not floating slightly above zero. This aspect allows performing an analysis between fluctuations on the range in which the Fed Fund Rate is targeted and the variation registered by a forecastable measures, such as the (modified) Taylor rule.

Even if it was not possible for the Federal Reserve to apply a negative Fed Fund Rate in the real world, to this need of support expressed by the economic conditions Monetary Authorities replied with a set of nonstandard measures. This support took the form of the Quantitative Easing and of the Forward Guidance, with the Federal Reserve including in its SOMA portfolio a wide range of securities usually not included in it. A similar measures has been proposed by Wu and Xia (2015)[16], which developed a Shadow Rate reflecting the monetary conditions in particular times. The idea behind the Wu-Xia shadow rate is that a market short rate allowed to fall under the zero lower bound can be an efficient metric in measuring the additional impact had by those policies that do not directly affect the Fed Fund Rate.

The metric proposed by Wu and Xia is although dated 2015, at the end of the zero lower bound period, while the methodology introduced by Taylor is dated well before 2008 and the linked financial crisis. Thereby, market operators were in those years more likely to form their expectations on some form of the Taylor Rule rather than on the Wu-Xia Shadow Rate; by that the expected component of the monetary intervention in the economic world would likely be a function of a Taylor-like estimation. These assumptions suggest a slight modification to the Kuttner Model applied in the “Empirical Analysis” chapter, transforming the formula used in the OLS Linear Model into:

16 J.Wu, F. Xia, **Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound,** 16th Jacques Polak Annual Research Conference Hosted by the International Monetary Fund, 2015

$$R_t = 1 + \beta_1 E[R_{un,t}] + \beta_2 MT_t + \varepsilon_t$$

MTt stands in the equation as the first difference of the variation between the Fed Fund Rate levels calculated by the Taylor Rule from the actual previous-month level of such rate. This new difference allows then to take into account the actual expected change over a wider set of measures, not taking into account the Fed Fund Rate target only. Running the OLS regression over the daily observations of Treasuries returns in the sample 2008-2019, it is possible to register an increase in the significance of the study, especially for the component that accounts for the expected change of monetary policies:

Crisis Times - EVENT DAYS – 2008-2019				
Dependent Variable	**d_ytm_1**	**d_ytm_3**	**d_ytm_6**	**d_ytm_12**
Intercept	-0.0002* (0.003)	- 0.00* (0.004)	- 0.0001* (0.000)	- 0.0004* (0.003)
R_un	0.003*** (0.001)	- 0.0109** (0.004)	- 0.0128*** (0.002)	- 0.0216 (0.041)
MT	-0.0014* (0.004)	- 0.0135* (0.009)	- 0.0092 (0.011)	- 0.032 (0.044)
R^2	**0.542**	**0.598**	**0.68**	**0.262**
F-Statistic	**2.857**	**3.025**	**12.39**	**0.3616**
P(F-Statistic)	**0.0651**	**0.0555**	**0.00**	**0.698**

Table 21 – Table representing the results of the Linear Regression performed over Treasury Bills' Returns using as independent variable the "Estimated unexpected change" and the variation in the difference between the actua value of the Federal Fund Rate and the estimation of the Taylor Rule. The sample taken into account is the one of "Event Days", and so of the ending days of the FOMC meetings in the years going from 2008 to 2019.

The achieved results shows support about the thesis that the Taylor rule can be used as a proxy for the expectations of market operators, and that implying them as an independent variable of the Linear Regression setup in analysing Treasury Bills' daily returns can be have a positive effect on the study. As it was using Re as expected component of the change, the setup seems to be extremely useful up to 6 months variations, while for longer periods the significance of the model decays, showing high p-values for both, coefficients and F-Statistics.

The principal result achieved by the employ of MT as independent variable is the opportunity to form consistent expectations over it, indeed even if the fundamentals composing it are disclosed quarterly, several estimations about their values are performed by several operators. This feature is denied when the actual change is used, as it is a metric observable only at the exact time of monetary policy change. Anyway it should be considered that the Federal Open Market Committee applies policies not just in function of a mathematical rule, but embedding in those policies discretion and "subjective" vision on a series of different factors affecting the real state of the economy. In every of its modification the Taylor rule would thereby not directly reflecting a "change" in the monetary conditions that the market would face in the next periods, but just a reasonable proxy of operators expectations.

Trading from previous results.

The previous sections are functional in order to allow the testing of a possible strategy involving the level of the Fed Fund Rate and US Treasuries. As already mentioned, the traditional setup results hardly applicable in the real world, as it bases it estimations over a set of information that is available only when disclosed, and by that already embedded into market prices, which indeed quite rapidly adjust to the incoming of a new stream of information. Forecasting values of the rates of Fed Funds Futures and over market operators' expectations would give the opportunity to rationalize the guess in the movements of the fundamentals of the model at least one day in advance. This time advantage is a necessary condition to form the trading signals that should be employed in order to put in practice evidences arising from the regressions performed previously.

The first signal that suggest the trigger of the strategy is the begin of the Federal Open Market Committee meeting, aspect that usually is disclosed well in advance, allowing the formation of the expectations well in advance.

Starting from the unexpected component of the monetary change, the estimation of Futures level represent the crucial aspect in determining next day level of Run, which in the expected setup becomes:

$$E_t[\Delta R_{un,t+1}] = \frac{dm}{(dm - t - 1)}(E_t[f_{t+1}^1] - f_t^1)$$

Thereby, if the expectation formed through the autoregressive model over next-day future rate results higher than the one registered on expectation day is possible to register a trading signal on such day. Indeed, proven that Run has a POSITIVE relationship with Treasury Bills' returns, an higher expected value of next day futures' rates would signal an increasing behaviour in returns of such securities. On the other hand, in the case of a lower expected value the signalling would suggest a descending behaviour of returns, suggesting opposite behaviour of rates of returns. This kind of analysis is functional in the determination of the position that should be taken during trading days in order to make a correct use of the information resulting from the coefficients associated to Run in the several regressions that were run on Treasury Bills.

The "expected component" of the monetary change estimated and presented in the studies performed by Kuttner (2001) and Bernanke and Kuttner (2005) does not seem to have a relevant impact over Treasuries' returns during the period in which the lower bound of the Fed Fund Target reached the zero. In those time it has been shown by the previous section that MT, the independent variable estimated as the difference between the actual value of the Fed Fund Rate and the one estimated through a Taylor rule, is able to offer better performances in the estimation of returns movements. This kind of estimator seems to have over mid-long T-Bills a higher impact than the one that it is possible to register for securities with a lower maturity. The level of such difference becomes than an additional strengthening of the signalling power expressed by the fluctuations of the Fed Fund Future.

Once defined the signalling determining the different positions required by a long short strategy, the next aspect to consider is the determination of the magnitude of such positions. Usually the weights of a long-short strategy are determined following several different rationale, often trying to pursue some kind of neutrality, or equalling the amount of the long and the short position, or trying to maintain a market exposure that can be considered as risk free. Often although, the short position is used partially or totally as the leverage necessary to fund the opening of a long position bigger than the one achievable using just the available cash in the balance sheet. The cost of such position will be registered in the portfolio profit and loss as a "minus return", representing the cost for the leverage necessary to invest in an additional portion of the long position. A long-short setup over securities that experience similar sign responses to the same variables, a position will be profitable if and only if the returns of the long position are higher than the ones of the short position, as the profit will arise from the (weighted) delta between the two returns.

From the regressions showed before, the Treasury Bills that showed the higher sensitivity to changes in the value of the two independent variables are the 6-months maturity ones, while the least responsive seemed to be the one-month ones. Then it would be reasonable to use the first between those securities as the instrument of the long position of the portfolio, while the other as the one to short in order to increase the long exposure leveraging.

Calculating than the daily returns of a portfolio with a relationship of 30-130%, with the left hand side representing the percentage of the balance used as short, while the other one the long exposure, over a time interval going from 2008 up to the first months of 2019. The days taken into account for the calculation of the returns are the Event Days, ad so those in which there would be a possibility for the Fed Fund Rate to change the interval in which this metric is allowed by the policies to vary, triggering than a series of effects over securities prices. The following table will present the effects the adjustments on the Treasury bills exposure a portfolio according to the variations expressed by the rate of one-month Fed Funds Futures, using the Autoregressive model previously presented as the instrument to form the expectations on next day Futures level.

ex_ret (bp)	13.2
t - stat	1.54
pvalue	0.064

Table 22 – The table presents the mean of the excess returns obtained as the difference between strategy's daily returns and the ones achievable investing in one-month Treasury Bills only. Returns data are expressed in basis points. The trigger for the trading is the forecasted value of the R_{un} metric

Adapting the holdings in Treasuries according to the variations in the forecasted values of the Futures rates would trigger quite low excess returns over the daily returns of a long only strategy with holdings only in one-months Treasury bills. In the previous table, the T-statistic and the p-value are the instruments to test if the excess returns in the model are significantly different from zero. While the t-stat is different from zero, the p-value suggests a level of significance slightly above the 5%. This level of the p-value suggests that the significance of such kind of strategy is quite limited, although the particular conditions under which the strategy was tested suggest that it is normal. Although if we consider that, in the interval going from 2009 up to the first months of 2019, the mean of daily returns in the one-month Treasury bills is almost zero; this value is even lower if considering only those days in which the Federal Open Market Committee announced its vision about the level of the Fed Fund Rate.

Including the effects achieved by adjusting the position according to the movement of the modified Taylor Rule. As already said in the dedicated paragraph, the Taylor Rule is an indicator used by market operators in order to gauge future movements in metrics targeted by the Federal Open Market Committee. The DT metrics presented in the modified model above can represents a good proxy of the expected component of the change in monetary policies, as it was R_e in the model studied by Kuttner. According to the previous results, the impact of this kind of metric should not be so substantial in the determination of the movements expressed by Treasury Bills on the FOMC ending days. The following table presents the results achievable by embedding such variable into the determination of the future level of the Fed Fund Rate.

ex_ret (bp)	13.3
t - stat	1.54
pvalue	0.059

Table 23 - The table presents the mean of the excess returns obtained as the difference between strategy's daily returns and the ones achievable investing in one-month Treasury Bills only. Returns data are expressed in basis points. The trigger for such strategy is represented by both the metrics $E[R_{un}]$ and DT.

The additional variable do not change too much the results obtained applying only the forecasted R_{un} variable. The only difference that is possible to see using even the expected component of the change as a trigger for the positions in the portfolio is a small reduction in the pvalue, when testing if the results are statistically different from zero. The impact that the fluctuations in the estimations resulting from the Taylor rule may thereby be already anticipated by the market, and do not have a too strong linkage that would ensure them as a valuable indicator of future market movements.

The results achieved in this chapter demonstrates that is possible to achieve a positive excess return on a daily basis, adjusting the positions in different maturity Treasury Bills according to the fluctuations of the Federal Fund Rate, and of related indicators of the behaviour of monetary policies. Anyway, the achieved returns would thereby be quite low, around the 13 basis points; furthermore in those results are not taken into account the relative costs related to such trading positions.

Conclusions

In this papers have been examined the existing relationship between Treasury Bonds and Stock Index with the fluctuations that monetary policies imposed to the market. Applying the rationale of the model ideated by Kenneth Kuttner to daily observations. This model has been applied to the securities even for the time interval that goes from the 2009 up to the first months of 2019. The OLS regressions seemed improved when taking into account only the observations relative to the final days of the Federal Open Market Committee, as is the moment in which the market absorb the information about the future path of the monetary policies. While stocks returns do not seem to be highly related with those fluctuations, with the OLS model achieving just modest levels in the coefficient of determination, the US Treasury market seems to be much more responsive to the FOMC announcements, especially for T-Bills up to 6-months maturity.

The second part of the paper examines the possibility to form a trading strategy starting from the previous results. In order to avoid the use of unknown information in the backtesting procedure of such strategy, two methods were applied in the formation of the trading signals. The rate of Futures on the Fed Fund Rate has been substituted by an autoregressive model, while the expected component has been substituted by a modified Taylor Rule, that going below the Fed Fund Rate zero-lower bound ideally captured the extraordinary monetary policies used in those years by the Federal Reserve. Although, even if this strategy presents a positive excess return, when compared to the daily returns of a Treasury Bill position, the low level of such daily returns do not allow it to be a stand-alone strategy, while would best fit as a method to rebalance the portfolio exposure to Treasury securities.

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