Managing Expectations:

Signalling effects of Federal Reserve Bank announcements over inflation expectations and expected real interest rates

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Abstract

Communication is an important aspect of modern monetary policy. Since the popularization of the inflation targeting framework, communication has been used to manage expectations and maintain credibility. In recent years, forward guidance as a signaling strategy has been recognized as an important tool of monetary policy. Can communication be considered an effective monetary policy tool? Using data from the United States, in a sample from 1990 to 2019, a Bai Perron test for multiple breakpoints is conducted to identify changes in both inflation expectations, term structure of the expectation, and expected real interest rates. We find evidence that changes in expectations for both inflation and real interest rates are associated with changes in central bank’s signaling strategy.

Key words: monetary policy, communication, signaling, forward guidance, inflation expectations, real interest rates expectations.
## Contents

Abstract ................................................................................................................................. 1
Summary ................................................................................................................................. 3
Introduction ........................................................................................................................... 5
1. Communication and monetary policy .............................................................................. 6
2. Theoretical Consideration ............................................................................................... 8
3. Previous Studies .............................................................................................................. 10
4. Theoretical Models ......................................................................................................... 11
   4.1. Forward guidance in a liquidity trap ......................................................................... 11
   4.2. Announcement effects in the Stock Market and financial assets ............................ 13
5. Empirical analysis .......................................................................................................... 14
   5.1. Data description ........................................................................................................ 14
   5.2. Empirical method ....................................................................................................... 19
   5.3. Empirical findings ...................................................................................................... 22
      5.3.1. Testing for structural changes in Inflation expectations ................................. 23
      5.3.2. Testing for structural changes in the Inflation expectations term structure .... 27
      5.3.3. Testing for structural changes in the real interest rates expectations ............ 30
      5.3.4. Testing for structural changes in the real rate term structure ...................... 33
Conclusions .......................................................................................................................... 36
References ........................................................................................................................... 38
Summary

In this study we analyze the effects of the central bank’s communication strategy over inflation expectations and expected real interest rates. We find evidence that changes in the communication strategy through signaling and commitments about the future path of monetary policy are associated with changes in expectations over inflation and real interest rates.

Communication has become an important part of modern monetary policy since the popularization of the inflation targeting framework. Because expectations about future conditions of the economy and future policy decisions are believed to be essential for the outcome of monetary policy, central banks need to be credible. Through strong commitments towards inflation targets and using a communication strategy as a tool to justify and explain policy decisions in the context of policy goals, central banks seek to maintain credibility and anchor expectations towards the desired level of inflation. Central banks also attempt to manage expectations about the future, especially over inflation and interest rates, by announcing or signaling the future path of monetary policy.

Although it had been used before, this type of communication strategy was systematically implemented in the aftermath of the financial crisis of 2008, when the main monetary policy instrument, the interest rate, was constrained by the zero bound in many countries. During the implementation of this strategy, usually referred to as “forward guidance”, the central banks not only signaled that would keep interest levels at low levels but also announced an explicit commitment to those rates for a certain period. However, the commitment with lower rates may conflict with the commitment to the inflation targets and can potentially create a credibility problem for the central bank.

To analyze the effects of the Central Bank’s attempt to manage expectations, we use data from the Federal Reserve of Cleveland for the United States, from 1990 to 2019. Although many studies have investigated the effects of such strategy over asset prices or nominal rates, we try to identify its impact over future inflation and real interest rates, which is its ultimate goal. Even though we find evidence that changes in the communication strategy through signaling and commitments about the future path of monetary policy are associated with changes in expectations over inflation and real interest rates, the direct causality remains
unclear. However, we find evidence that the signaling strategy over interest rate did not compromise the credibility over the inflation targets.
Introduction

Communication is an important aspect of modern monetary policy. Since the popularization of the inflation targeting framework, communication has been used to manage expectations and maintain credibility, not only by strengthening the commitments to the targets, but also to explain and justify policy decisions in the context of those targets. In recent years, forward guidance as a signaling strategy has been recognized as an important tool of monetary policy, in which promises about future path of interest rates are expected to have an impact on the economy.

While the signaling strategy began to be systematically explored in the aftermath of the great financial crisis of 2008, as the interest rates approached zero in many countries, it had been used before. In the United States, at least two other episodes are well documented were the central bank and central bank officials used signaling to influence expectations. The first one is the asset price bubble of 1995, commonly referred as “irrational exuberance”, and the second, the end of interest rates cycle of 2003, during which the nominal rate approached zero for the first time. However, the effects of central bank attempts to manage expectations are unclear.

What is the role of communication in monetary policy? Can communication be considered an effective monetary policy tool? This study aims to contribute to these broad questions this as it to identify the signaling effects of federal reserve announcements over inflation expectations, term structure of the expectations, and future real interest rates. Two main hypotheses are tested: “Are monetary policy announcements signaling future path of interest rates associated with changes forward real interest rates?” and “Are monetary policy announcements signaling the future path of interest rates in the future following policy decisions associated with changes in the inflation expectation rates?”

To answer these questions, this study analyzes data for the United States from 1990 to 2019. While there are plenty of research on the effects of forward guidance in asset prices and nominal rates, we attempt to identify its impact on the expectations over inflation and real interest rates, which is the ultimate goal of the strategy. We use data from the Federal Reserve Bank of Cleveland for inflation expectations and real interest rates over several time horizons. This data also allows to measure the term structure for inflation expectations, as well as for the real interest rates. A Bai-Perron test for multiple breakpoints is conducted to test for
structural breaks and to estimate break dates for the variable. We then compare the estimated break dates to changes in the Central Bank communication strategy. While evidence of structural breaks in inflation expectations, term structure of the expectations, and forward real interest rates are found in dates consistent with the episodes we attempt to analyze, the causal relation still remains unclear, as some of the break dates precede changes in central bank communication.

This study is divided in five sections. The first section presents a background discussion over the relevance of communication and monetary policy, followed by a preliminary theoretical discussion over how these phenomena can be explained. In the third section, two simplified models are presented to express the impact of central bank announcements over expectations and asset prices. In the fourth section, there is a summary of important empirical findings from other authors. The fifth and last section will present the empirical findings based on the data selected and the empirical model of choice.

1. Communication and monetary policy

Before the 1990s it was common for central banks to conduct monetary policy within a discretionary approach. The general belief was that, in order to be successful, policy decisions had to surprise the market (Pole, 2005). However, as highlighted by Barro and Gordon (1983), while unanticipated monetary policy could be successful, it creates a problem of time inconsistency. If the central bank is able to produce surprise inflation and economic agents are rational and forward looking, the commitments toward price stability will not be credible. This is especially true if we consider that market distortions can lead to social loss attributed to an inefficiently low output and, consequently, an inflationary bias (considering a Calvo price setting model).

In order to solve the credibility problem, many countries have established an independent mandate to the central bank and adopted an inflation targeting regime with a rule-based approach to monetary policy with public commitments to price stability. While most adopted explicit targets of usually around 2%, some used implicit targets, as is the case of the Federal Reserve until 2012. Within this framework, managing expectations is a key element for monetary policy. If agents believe in the announcements made by the central bank, it will
be able to anchor inflation expectations and monetary policy could be successful in maintaining price stability.

However, managing expectations can be complicated by the limitations of stabilization policies due to imperfect information that can result in uncertainty. Monetary policy effects on the economy work with long lags and changes in policies due to shocks take time to take effect. Imperfect information about the structure of the economy can lead to uncertainty regarding the magnitude and time lag of changes in monetary policy. Additionally, imperfect information about the current and future state of the economy can lead to measurement errors in output and inflation gaps, which can lead to overestimation or underestimation of the optimal policy response (Orphanides, 2003). Lastly, imperfect information on the nature of the shocks hitting the economy can also lead to uncertainty about the effects of monetary policy.

Due to different sources of uncertainty regarding the economy and the effects of monetary policy, Central Bank’s communication about its policy decisions and goals can support anchoring of expectations and, thus, increase monetary policy effectiveness. Reassurance of the monetary policy goals, as well as the reasoning behind policy decisions can maintain credibility in face of uncertainty and temporary deviations from the policy targets.

Managing expectations can assume different dimensions when dealing with “dark corners” of monetary policy. Managing forward-looking expectations in a liquidity trap or under the “zero-bound” limit to the nominal interest rates was tested by many countries in the aftermath of the financial crisis of 2008. Under the rational expectation hypothesis, the current output gap depends not only on the current real interest rate, but also the expected future real interest rates (Walsh, 2009). If policy is credible, the central bank can stimulate demand by promising to follow a more expansionary monetary policy in the future.

While this policy has been ever since widely adopted, its effects on the economy are disputed. This so-called forward guidance strategy can create a time inconsistency problem, where the short-term objectives of stimulating demand can conflict with the long-term goal of price stability and, hence, inefficiently anchoring expectations. In order words, establishing commitments to a certain future path of interest rate may weaken the commitment to the inflation targets. Incompatible commitments would undermine the overall monetary policy credibility. On the contrary view, by signaling the future path of monetary policy, the central
bank can reduce the uncertainty and anchor expectations and asset prices to levels which are compatible with the policy goals.

2. Theoretical Consideration

According to Woodford (2005), because economic agents are forward-looking, central banks affect the economy as much through their influence over expectations as through the effective open market operations. The author goes as far to claim that “not only do expectations about policy matter, but, at least under current conditions, very little else matters”. Increased sophistication in the financial system have made more difficult to control and regulate financial markets. Changes in the level of the overnight interest rate are only important for decision making if it affects the opportunity cost perception in terms of the cost of borrowing. In other words, it is relevant only if it can affect financial asset prices, such as longer-term interest rates, equity prices and exchange rates. Woodford concludes that, the public understanding of not only central banks’ current actions, but also of what can be expected in the future is critical to the effectiveness of monetary policy.

Woodford (2005) classifies central banks’ communication in four types/topics. The first one would be an expression about current conditions in the economy, that can justify the policy decisions. The policy decision itself regarding the targets for interest rates would be the second. The third type of communication contains a revelation of the strategy used by the central bank in order to achieve its goals. The fourth and last type would be statements about the outlook for future policy. This set of communication is important to the verifiability of the central banks’ commitment. Because it is unlikely that the target will be always achieved, communication justifying policy decisions can reassure agents on central banks commitments in a rule-based approach to monetary policy. Another argument that stresses the importance of communication is related to the complexity of the economy. Central banks understanding of the transmission mechanisms of monetary policy is always evolving and, consequently, the optimal policy response will change given the circumstances and the central bank would benefit when those changes are clear to the public.

Nevertheless, the desirability of central bank communication can be questioned. According to Woodford (2005), one could argue that increasing transparency and predictability of central banks actions would not be desirable as the surprise element can lead
to a greater impact over market rates, by exploiting temporary illiquidity of the markets. However, it is unclear if this temporary effect implies in a greater transmission mechanism.

Morris and Shin (2002) also show some disadvantages of public information provision. The authors express the information provision as a “beauty contest” game, where each participant is concern not only on choosing the optimal action, but also an action that is not too far from others’ actions. According to this model, increasing the precision of public signals has an ambiguous impact on social welfare. While it can increase the accuracy of actions for each agent, it can also make the average action less appropriate to the current state of the economy, because more weight is placed on the public signal than the individual evaluation. While individual errors have no effect on the average, public errors would affect all the actions. However, in order to the second effect to dominate, as pointed out by Svenson (2005), the precision of each participant must be at least 8 times as great as the precision of the public signal.

McKay, Nakamura and Steinsson (2016) show that the magnitude of the effects of forward guidance in New Keynesian DSGE models can be large. Considering a promise of a 1 percentage point lower real interest rate for a single quarter, the effect on inflation is 18 times larger when the promise affects the five-year rate than over the current interest rate. This happens because, in these models, the consumption determined by the Euler equation has a large cumulative response. Also, since the announcement also affects current inflation, at the zero lower bound, this would lead to lower real rates and create a positive feedback loop on output.

Despite the substantial conclusions of the model, the authors question if they would be realistic. Consumption could be limited by borrowing constrains and a precautionary savings attitude due to a greater perception of income risk. Including those elements in a model with incomplete markets and household heterogeneity yields a different result and forward guidance becomes less effective compared to the original model. The augmented model shows that forward guidance has only about 40% as large an effect on current consumption, that can be accredit to a precautionary savings effect that counteracts the intertemporal substitution of standard models. McKay et al (2016) also mentions similar results from other authors that consider different models, such as Carlstrom, Fuerst, and Paustian (2012) and Kiley (2014) that show that the magnitude of the forward guidance is reduced in a sticky information model, because it conveys a Phillips curve with sticky information that is less forward looking.
3. Previous Studies

Gürkaynak, Sack and Swanson (2004), using high frequency data showed that signaling a “future path of policy” associated with FOMC (Federal Open Market Committee) statements have a significant impact on asset prices, especially on longer-term Treasury yields. Using a data set going back to 1990 that captures changes in asset prices within a 30 minute and 1 hour window surrounding the FOMC announcement, the authors measure the response of asset prices to both monetary policy actions and statements. Using structural factor analysis, they conclude that movements around monetary policy announcements in federal funds futures and Eurodollar future contracts can be characterized by two dimensions: surprise in the federal funds rate target factor and a path factor. They found that, a 1 percentage point surprise tightening in the federal fund rates lead to a decline of 4.3% in the S&P500 and increases of 47, 27, and 12 bp in 2, 5, and 10-year Treasury yields. As for the path factor, they found that it has a much greater impact on the long end of the yield curve, with a 1 percentage point innovation causing responses of 36 and 27 bp in five- and ten-year Treasury yields.

Considering that under a rule-base model of monetary policy, the role of central bank communication includes transparency and predictability. Therefore, one way of evaluating the success in communication is by measuring the level of surprise in monetary policy. Low levels of surprise indicate more predictability and effectiveness of the communication strategy. Additionally, the communication strategy aims also to manage expectations. Change in asset prices following policy announcements is one way of measuring this effect. In fact, when both effects are combined, we have a “forward guidance effect”.

Woodford (2005) made an event analysis of the effects of monetary policy during the year of 2003, when the fed funds rate had been reduced to 1.0 and, thus, was close to the zero bound. The FOMC implemented a communication strategy of forward guidance to signal that would not raise rates without some months of advance warning, using the expression “considerable period” repeatedly in several statements. According to the author, this strategy was successful in substituting interest rate cuts. A communication strategy was also used in the transition to a higher level for the fed funds rate, avoiding a bond market to overshoot and reducing uncertainty. Woodford also highlights Gürkaynak conclusions discussed above,
regarding the effectiveness of communication being measured by the low level of the “surprise component (surprise factor)” of each fed funds rate and also by the presence the “slope surprise (path factor)” of the term structure after policy announcements.

In the article “Shocking Language: Understanding the macroeconomics effects of central bank communication” from Hansen and McMahon (2016), the authors explore how the information released by the members of Federal Open Market Committee impact economic variables. They use a computational linguistics approach to text analysis to measure the content of different documents and seek to analyze the communication through three dimensions: stance of current monetary policy, views about the economy, and forward guidance. They find that the communication on future interest rates (forward guidance) is much more important than the other two dimensions analyzed.

4. Theoretical Models

In this section, two theoretical models are selected. To show the importance of inflation expectations and the expectations over real interest rates in the future to the output gap and consequently, as a potentially important transmission mechanism in monetary policy, we address a forward guidance model in a liquidity trap in the section 3.1. In section 3.2, a model for announcement effects in stock markets and financial assets is presented to illustrate how announcements over future changes in policy can impact current asset prices. Both models explain not only the importance of expectations, but also how signaling can impact asset prices and the opportunity cost perception.

4.1. Forward guidance in a liquidity trap

Considering an economy hit by a large negative demand shock and where the policy response is constrained by a zero bound on the nominal interest rate. Using a model specified by Walsh (2009), Woodford (2005) and Jacob and Sorensen (2010), let us consider a variable $v_t$ that reflects the private sector confidence over the economy and is one of the factors that determine the level of consumption and investment. This variable $v_t$ also corresponds to demand shocks, since sudden and unexpected events that increases or decreases demand are related to changes in consumers’ and investors’ perceptions about the economy. Considering a
simplified version of the aggregate demand curve, where the deviation of output \( y_t \) from its long-term level \( \bar{y} \) can be approximated by a linear function of the deviation of the real interest rate \( r_t \) from its trend level \( \bar{r} \). The term \( v_t \) captures the demand shocks that can be related to economic agents’ confidence. We have:

\[
y_t - \bar{y} = -\alpha_2 (r_t - \bar{r}) + v_t. \tag{1}
\]

The demand shock \( v_t \) can be expressed by the expected levels of output gap in the future and \( a_t \) is a stochastic variable, we can assume that:

\[
v_t = y_{t+1}^e - \bar{y} + a_t, \quad E[a_t] = 0, \quad E[a_t a_j] = 0, \quad j \neq t \tag{2}
\]

Since \( r_t = i_t - \pi_t^e \), the goods market equilibrium condition is:

\[
y_t - \bar{y} = v_t - \alpha_2 (i_t - \pi_t^e - \bar{r}). \tag{3}
\]

Using the expectational operator, we have:

\[
y_{t+1}^e - \bar{y} = v_{t+1}^e - \alpha_2 (i_{t+1}^e - \pi_{t+1}^e - \bar{r}), \quad \text{and} \quad v_{t+1}^e = y_{t+2}^e - \bar{y}. \tag{4}
\]

Therefore, we can express the output gap as the following:

\[
y_t - \bar{y} = a_t + \alpha_2 (i_t - \pi_t^e - \bar{r}) - \alpha_2 \sum_{j=1}^{\infty} (i_{t+j}^e - \pi_{t+j}^e - \bar{r}). \tag{5}
\]

We can conclude that under the rational expectation hypothesis, agents are forward looking and make decisions about consumption and investments considering not only the current interest rates but also the future path of interest rates and inflation.

Considering a liquidity trap situation, where the interest rate is bound by the zero level and \( i_t = 0 \), we have:

\[
y_t - \bar{y} = a_t + \alpha_2 (\bar{r} + \pi_{t+1}^e) - \alpha_2 \sum_{j=1}^{\infty} (i_{t+j}^e - \pi_{t+j+1}^e - \bar{r}). \tag{6}
\]

From which we can conclude that in a liquidity trap, when the interest rate is restricted by the zero bound, if the central bank makes a credible announcement to keep the future path of the interest rates in lower level than in the past, or alternatively, if the central bank can promise to increase future inflation, it can positively impact the output gap. However, this signaling strategy may be subject to time inconsistency issues. When implementing this strategy, the Central Bank expects that there is enough slack in the economy and the expected time lags for the response from expansionary policies are long, therefore, the announcement will be time consistent. Still, even considering large demand shocks associated with long time
lags, the “forward guidance” strategy can fundamentally and intrinsically have a time inconsistency problem. However long the zero bound constrain may be, the longer term of monetary policy under the inflation targeting framework is price stability, thus, the “shorter-term” goal of higher inflation may be in conflict with the “longer-term” inflation target.

4.2. Announcement effects in the Stock Market and financial assets

Considering an economy where agents are forward looking, announcements about changes in economic policy can have an impact in the economy even before they are implemented. Considering a simple model of the stock market, derived from a model discussed in Jacobsen and Soren (2010) to measure announcements regarding dividends, the market value of shares at a period $S_t$ is given by the discounted value of expected future dividends $D_{t,t+n}^e$. If the discount factor is given by the expected interest rates, we have:

$$S_t = D_t^e + \frac{D_{t+1,t}^e}{1+r_{t+1}^e} + \frac{D_{t+2,t}^e}{(1+r_{t+1}^e)^2} + \cdots + \frac{D_{t+n,t}^e}{(1+r)^n}. \quad (7)$$

Suppose that the actual dividend $d_{t+n}$ has a stochastic component around its mean, we have:

$$d_{t+n} = \bar{d} + \varepsilon_{t+n}, \text{ and } E(\varepsilon_t) = 0. \quad (8)$$

Suppose the central bank follows a policy rule in which the nominal market interest rate $i_t$ is determined by the natural real interest rate and the expected inflation, and react to both the deviation of inflation $\pi_t$ from its target $\pi^*$ and the deviation from output $y_t$ from its natural level $\bar{y}$, as such:

$$i_t = \bar{r} + \pi_{t+1}^e + h(\pi_t - \pi^*) + b(y_t - \bar{y}). \quad (9)$$

Since the real interest rate is given by $r_t = i_t - \pi_t^e$, and considering that the monetary policy affects the economy with lags, and therefore uses an inflation forecast policy rule, we can rewrite the policy rule as the following:

$$r_t = \bar{r} + h(\pi_{t,t-1}^e - \pi^*) + b(y_{t,t-1}^e - \bar{y}). \quad (10)$$

---

1 The reference here is to the “Introducing Advanced Macroeconomics” textbook version of the model. This modified version also needs some development. The original reference is unknown since it is not cited by the authors.
If we assume that expectations are anchored, then $E(\pi_{t+n-1}) = \pi^*$, and $E(y_{t+n-1}^e) = 0$, we have:

$$r_{t+n}^e = \bar{r}, \text{ and } S_t = \frac{\bar{d}}{\bar{r}} \text{ if } r_t > 0.$$  \hfill (11)

Suppose that the central bank announces that it will keep the interest rate lower in the future compared to what it did in the past under a forward guidance policy. This implies that:

$$r_{t+n}^e = r^*; \quad r^* < \bar{r}.$$  \hfill (12)

Since the market value of shares are conditioned to the expected interest rates, the impact of the announcement will be an increase in $S_t$, given that:

$$S_{t0} = \frac{\bar{d}}{\bar{r}} < S_{t1} = \frac{\bar{d}}{r^*}.$$  \hfill (13)

This strategy will work once the level $r^* < \bar{r}$ is expected to hold for a long period of time, and the interest rate reduction is perceived as quasi-permanent. Since a quasi-permanent reduction in the average interest rate to levels below the natural rate can also have an impact on the inflation and the output gap, the expected interest rate will fall to the new levels only if the expected policy response to inflationary pressures do not offset the short-term announcement. As explained in the previous section, the central bank announcement is also subject to time inconsistency problems. By pursuing this strategy, the Central Bank hopes that, if there is enough slack in the economy and the expected time lags for the response from expansionary policies are long, the announcement will be time consistent.

5. Empirical analysis

5.1. Data description

To analyze the effects of the communication strategy of the central bank on expectations, monthly data from the United States from 1990 to 2019 was used. The choice of the time period reflects the adoption by the Federal Reserve of many elements of the inflation targeting framework, which includes communication as an important component of monetary policy. The sample was also restricted to the forward guidance period, from December 2008 to December 2019. This study seeks to contribute to literature by attempting to estimate the effects of changes in the Federal Reserve signaling over inflation expectations as well as the
expected real interest rates. Although nominal rates are important, the main goal of monetary policy is to impact real rates, which ultimately reflect the real opportunity cost for economic agents when making decisions about consumption and investment.

Data from the Federal Reserve Bank of Cleveland was used to measure both the expectations over future inflation and real interest rates over different time horizons. The data uses a methodology developed by Haubrich et. al. (2011) that incorporates inflation swap rates, nominal treasury yields and surveyed forecasts of inflation. The real yields are calculated from taking the difference between equivalent maturity nominal yields and inflation swap rates instead of the more commonly used TIPS yields.

In the graph below, it is possible to visualize the ten-year expected inflation estimated by the Federal Reserve Bank of Cleveland. One can observe that, during the period, a clear downward trend in the long-term inflation expectations towards converging to the inflation target even before 2012, when the Federal Reserve finally adopted an explicit target of the explicit target of 2%.

Graph 1 – One-, five- and ten-year expected inflation rates

Source: Federal Reserve Bank of Cleveland.

The methodology of the Federal Reserve Bank of Cleveland also provides a measure of real forward rates. The forward rates available in real terms are the one-month, one-year and 10-year, as can be observed in the graph as follows.
As can examine from the graph bellow, the real rate calculated from the model differs from the real rate estimated by the YIPS Yield, especially during the financial crisis of 2008. According to Haubrich et al (2011), this is due to the fact that TIPS present a liquidity premium and, therefore, it is not a reliable measure of real rates.

Source: Federal Reserve Bank of Cleveland.

To identify changes in the central bank communication strategy, the detailed forward guidance timeline disclosed by the Federal Reserve Bank was used. Other events were also
considered, such as, the “irrational exuberance” speech given by the then Federal Reserve Bank chairman Alan Greenspan in December of 1996, and the 2003 communication strategy as the interest rate approached values close to zero for the first time. In the graph below, it is possible to follow a timeline for the forward guidance period that began in the end of 2008 and its impact on nominal rates.

Graph 4 – Forward guidance timeline


According to the Federal Reserve Board, the important data points for the forward guidance strategy period are:

- December 16, 2008: The FOMC lowers its target for the federal funds rate to a range of 0 to 1/4 percent, which the FOMC considers to be an effective lower bound.
- March 18, 2009: The FOMC replaces "for some time" with "for an extended period" in its post meeting statement.
- August 9, 2011: The FOMC announces it will likely keep the federal funds rate at exceptionally low levels "at least through mid-2013."
- January 25, 2012: The FOMC replaces "at least through mid-2013" with "at least through late 2014."
• September 13, 2012: The FOMC states that it "exceptionally low levels for the federal funds rate are likely to be warranted "at least through mid-2015."

• December 12, 2012: The FOMC introduces threshold-based and that it anticipates that this exceptionally long range would be maintained "at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored."

• December 18, 2013: The FOMC announces it "likely will be appropriate to maintain the current target range for the federal funds rate well past the time that the unemployment rate declines below 6-1/2 percent”

• March 19, 2014: The FOMC replaces its threshold-based forward guidance with the statement that it expects it likely will be appropriate to maintain the current target range for the federal funds rate for "a considerable time"

• October 29, 2014: The FOMC states that "it likely will be appropriate to maintain the 0 to 1/4 percent target range for the federal funds rate for a considerable time. "However, if incoming information indicates faster progress …, then increases in the target range for the federal funds rate are likely to occur sooner than currently anticipated"

• December 17, 2014: The FOMC announces that "it can be patient in beginning to normalize the stance of monetary policy."

• March 18, 2015: The FOMC replaces the indication that "it can be patient" with the indication that an increase in the target range "remains unlikely at the April FOMC meeting.

• July 29, 2015: The FOMC alters the guidance referring to "further improvement" in the labor market to "some further improvement."

• October 28, 2015: The FOMC replaces the clause "how long it will be appropriate to maintain [the target range]" with "whether it will be appropriate to raise the target range at its next meeting."

• December 16, 2015: The FOMC raises the target range for the first time since before the financial crisis.

• March 15, 2017: The mention of "only gradual increases" in the future path of the federal funds rate is changed to "gradual increases." Also, the statement
now emphasizes the Committee's "symmetric inflation goal" instead of its "inflation goal."

- January 31, 2018: The expression "gradual increases" is changed to "further gradual increases."
- June 13, 2018: The FOMC drops the sentence indicating that the federal funds rate is "likely to remain, for some time, below levels that are expected to prevail in the longer run."
- September 26, 2018: The FOMC drops a sentence indicating that "the stance of monetary policy remains accommodative," which had been in place since December 2015.
- January 30, 2019: The FOMC no longer indicates a judgment that "some further gradual increases [in the target range for the federal funds rate] will be consistent" with sustained expansion of economic activity, strong labor market conditions, and inflation near the Committee's symmetric 2 percent objective. Instead, the FOMC conveys that it "will be patient as it determines what future adjustments to the target range […] may be appropriate to support these outcomes."

In addition to these data points, it is also possible to analyze other two important dates in which is believed that the communication had an important effect:

- December 5, 1996: Alan Greenspan, then chairman of the Federal Reserve, gave the speeches: “The Challenge of Central Banking in a Democratic Society.”, in which he coined the term “irrational exuberance” to describe a possible asset bubble.
- August 2003: The Federal Funds rate approaches the zero bound five years before the great financial crisis and signaling as a monetary policy tool is considered.

5.2. Empirical method

The method of choice to estimate the impact of changes in real rates and inflation expectations is the structural change test and model developed by Bai and Perron (1998, 2000 and 2003) that allows for multiple breakpoints in the estimation of linear models. Using a
dynamic programming algorithm, it is possible to estimate break-dates as global minimizers of the sum of squared residuals for the possible segments. It is also possible to estimate parameters for each segment of the structural changes. After estimating breakpoints dates, we then compare with the identified changes in central bank communication. The authors describe the model as follows.

Considering a linear regression with m breaks and \( m+1 \) regimes:

\[
y_t = x_t' \beta + z_t' \delta_j + u_t, \quad t = T_{j-1} + 1, ..., T_j, \quad \text{for } j = 1, ..., m + 1 \quad (14)
\]

Where \( y_t \) is the observed dependent variable time \( t \); \( x_t(p \times 1) \) and \( z_t(q \times 1) \) are vectors of covariates and \( \beta \) and \( \delta_j(j = 1, ..., m + 1) \) are the vectors of coefficients; \( u_t \) is the disturbance at time \( t \). The indices \( T_1, ..., T_m \) are the break points and are treated as unknown as well as the coefficients. If all coefficients are subject to change, \( \beta = 0 \). In this model, the variance of \( u_t \) does not need to be constant since breaks in variance are permitted when they occur simultaneously to the breaks in parameters.

The model is estimated based on the least-squares principle, where for each m-partition \( (T_1, ..., T_m) \), the associated least-squares estimates \( \beta \) and \( \delta_j \) are obtained by minimizing the sum of squared residuals. Considering that the linear regression before can be expressed in matrix form, we have:

\[
Y = X\beta + \bar{Z}\delta + U
\]  \quad (15)

The model is estimated based on the least-squares principle, where for each m-partition \( (T_1, ..., T_m) \), the associated least-squares estimates \( \beta \) and \( \delta_j \) are obtained by minimizing the sum of squared residuals, as follows:

\[
(Y - X\beta - \bar{Z}\delta)'(Y - X\beta - \bar{Z}\delta) = \Sigma_{i=1}^{m+1} \Sigma_{t=T_{i-1}+1}^{T_i} [y_t - x_t' \beta \delta_i]^2
\]  \quad (16)

If the parameters \( \hat{\beta}(\{T_j\}) \) and \( \hat{\delta}(\{T_j\}) \) denote estimates based on the given m-partition \( (T_1, ..., T_m) \) denoted \( \{T_j\} \), the estimated breakpoint are such that minimize sum of square residuals from the equation above, denoted as a function \( S_T(T_1, ..., T_m) \), such that:

\[
(\hat{T}_1, ..., \hat{T}_m) = \text{argmin}_{T_1, ..., T_m} S_T(T_1, ..., T_m), \quad \text{where } T_i - T_{i-1} \geq q^2
\]  \quad (17)

Within the model framework, it is also possible to implement tests statistics for multiple breaks. For this empirical analysis, the chosen methodology is the sequentially determined break tests, as proposed by the authors, in which a test for \( L \) versus \( L + 1 \) breaks
is conducted. The Null hypothesis is “no structural change” and the alternative hypothesis is “a single change”. The test is applied to each segment, from $\tilde{T}_{i-1}$ to $\tilde{T}_i$ ($i = 1, ..., L + 1$) in a model with $(L + 1)$ breaks. The null hypothesis is rejected in favor of the $(L + 1)$ model if the minimal value of the estimated residuals is sufficiently smaller than the sum of the square residuals from the $L$ breaks model. We perform the multiple breakpoint test in two different models. In both models the benchmark approach of allowing for 5 breaks and a trimming of $\varepsilon = 0.15$ is chosen. For this choice of parameters, each segment has at least 15 observations.

In the first model, we estimate the target variable (measures of inflation expectations or forward real rates) against a constant. In this case, not only $\beta_t = \mathbf{0}$, but also $z_t = \mathbf{1}$. Given that we aim to estimate the same model for expected inflation ($\pi^e$) and expected real interest rate ($r^e$), from equation (14), we have:

$$
\pi^e_t = \delta_j + u_t, \quad t = T_{j-1} + 1, ..., T_j, \quad \text{for } j = 1, ..., m + 1
$$

(18)

$$
\gamma^e_t = \gamma_j + u_t, \quad t = T_{j-1} + 1, ..., T_j, \quad \text{for } j = 1, ..., m + 1
$$

(19)

The terms $\delta_j$ and $\gamma_j$ correspond to the constant term in a simple OLS regression. In our breakpoint estimated regressions, $\delta_j$ and $\gamma_j$ vary according to the m-partitions, as specified in (14). The constant terms capture the overall average expected variable (inflation or interest rates). We use the Bai and Perron (2003) methodology to test for m-partitions (in our case we test for a maximum number of 5) and estimate breakpoint dates. The goal of the test is to identify changes in the long-term average of the target variables throughout different business cycles. These changes can be provoked by permanent shocks that change the agents’ perspective on long term inflation or real interest rates, such as changes in the structure of the economy or, as the hypothesis we seek to test, changes in the commitments made by the Central Bank that could lead to anchoring of expectations to new levels. Later, we compare the breakpoint dates to the dates when changes in the communication strategy were identified.

In the second model we estimate the covariance parameters between two points of the term structure of the target variable, by running a linear regression of the long-term expectation on the short-term expectation. As in the first model, we consider $\beta = \mathbf{0}$ and allow for breakpoints in all the variables. In the vector of covariates, we include a constant term and a measure for the short-term expectations. The same model is estimated for both the inflation
expectations, as well as the expected interest rates. Applying this specification to equation (14), we have:

\[ \pi_{te}^t = \alpha_{1j} + \pi_{se}^t \delta_j + u_{1t}, \quad t = T_{j-1} + 1, \ldots, T_j, \quad \text{for } j = 1, \ldots, m + 1 \] (20)

\[ r_{te}^t = \alpha_{2j} + r_{se}^t \gamma_j + u_{2t}, \quad t = T_{j-1} + 1, \ldots, T_j, \quad \text{for } j = 1, \ldots, m + 1 \] (21)

In equation (20) \( \pi_{te}^t \) is a measure of the long-term inflation expectations in time \( t \), and \( \pi_{te}^t \) is a measure of the short-term inflation expectation at the time \( t \). The term \( \alpha_{1j} \) is a constant term, which is subjected to \( j \) partitions related to the \( m \) number of estimated breaks. The term \( u_{1t} \) capture the disturbance term at the time \( t \).

Similarly, in equation (21) \( r_{te}^t \) is a measure of the long-term expected real interest rate in time \( t \), and \( r_{te}^t \) is a measure of the short-term expected interest rate at the time \( t \). The term \( \alpha_{2j} \) is a constant term, which is subjected to \( j \) partitions related to the \( m \) number of estimated breaks. Finally, the term \( u_{2t} \) capture the disturbance term at the time \( t \).

The Bai Perron test is also conducted to estimate multiple breakpoints on the model. The purpose of this exercise is to capture possible changes on the term structure of the real interest rates as well as term structure for the inflation expectations. Changes in the term structure of the target variables can reflect changes of the expectations regarding the future path of monetary policy in the long run. According to Browne and Manasse (1989), applying the rational expectations hypothesis to the term structure implies that the long term-interest rate is a weighted average of the present and expected future short-term interest rates and a risk premium. The term structure for nominal interest rates has been usually utilized as an indicator of market’s expectations regarding inflation and output. Therefore, the term structure of both real interest rate and the inflation expectations can measure the expectations regarding changes in monetary policy and corresponding business cycles.

5.3. Empirical findings

This section will present the results for the models that were estimated. First, we test for multiple breakpoints in the inflation expectations, as specified in equation (18) for different time-periods ahead. We then proceed to test for breakpoints in the inflation term structures by testing for structural changes in the covariance between long-term and short-
term inflation expectations, as specified in equation (20) analyzing the covariance between one and five years, and between one and ten years. The same model is tested also for the real interest rates. First, we conduct the multiple breakpoints test for real interest rates, as specified in equation (19) for one month, one year and ten years forward. Later, we test for breakpoints in the term structure, as specified in equation (21) by analyzing the covariance between the one month and one-year rates and between the one-month and ten-years rate. The case in which we are able to find breakpoints in the model estimated, suggest structural changes in the variables that may be connected to changes in the communication strategy by the central bank. We find evidence for breakpoints in both models, as well as for both variable classes: inflation expectations and expected real rates.

To test for break dates using linear models and applying the Bai-Perron sequential test, the variables included must be stationary. Using an augmented Dickey-Fuller test, the results indicate that the variables we analyze in the model are stationary. The table 1 bellow show a summary of the Augmented Dickey-Fuller Unit Root test in which we can reject the null hypothesis that the variables tested have a unit root based on a 5% level.

Table 1 – Standard Unit Root test – Augmented Dickey-Fuller test statistics

<table>
<thead>
<tr>
<th>Variables tested</th>
<th>Exogenous var.</th>
<th>Lag Length *</th>
<th>t-Statistic</th>
<th>Critical value**</th>
<th>Prob.***</th>
</tr>
</thead>
<tbody>
<tr>
<td>1y inflation exp.</td>
<td>Constant, linear trend</td>
<td>6</td>
<td>-3.584438</td>
<td>-3.422356</td>
<td>0.0325</td>
</tr>
<tr>
<td>5y inflation exp.</td>
<td>Constant, linear trend</td>
<td>0</td>
<td>-3.602518</td>
<td>-3.422356</td>
<td>0.0309</td>
</tr>
<tr>
<td>10y inflation exp.</td>
<td>Constant, linear trend</td>
<td>0</td>
<td>-3.600106</td>
<td>-3.422356</td>
<td>0.0312</td>
</tr>
<tr>
<td>15y inflation exp.</td>
<td>Constant, linear trend</td>
<td>0</td>
<td>-3.654995</td>
<td>-3.422356</td>
<td>0.0267</td>
</tr>
<tr>
<td>20y inflation exp.</td>
<td>Constant, linear trend</td>
<td>0</td>
<td>-3.694856</td>
<td>-3.422356</td>
<td>0.0239</td>
</tr>
<tr>
<td>1m real rate</td>
<td>Constant, linear trend</td>
<td>1</td>
<td>-5.329042</td>
<td>-3.422356</td>
<td>0.0001</td>
</tr>
<tr>
<td>1y real rate</td>
<td>Constant, linear trend</td>
<td>1</td>
<td>-4.364768</td>
<td>-3.422356</td>
<td>0.0028</td>
</tr>
<tr>
<td>10y real rate</td>
<td>Constant, linear trend</td>
<td>0</td>
<td>-3.621295</td>
<td>-3.422356</td>
<td>0.0294</td>
</tr>
</tbody>
</table>

* Based on SIC
** 5% level
*** Mackinnon (1996) p-values

5.3.1. Testing for structural changes in Inflation expectations

In Table 3 it is presented the summary of results when the Bai-Perron test for structural change is implemented for inflation expectations for different time-periods ahead: one, five, 10, 15 and 20 years. In this first model we consider only one breaking variable,
according to the specification described in equation (18), a constant term that capture possible structural changes in the average inflation expectations over different time spans. The test is conducted in a sample that begins in January of 1990 and ends in December of 2019.

Table 3 - Test for structural changes - Inflation Expectations

Bai-Perron tests of L+1 vs. Sequentially determined breaks

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking Variables</td>
<td>constant</td>
<td>constant</td>
<td>constant</td>
<td>constant</td>
<td>constant</td>
</tr>
<tr>
<td>Number of breaks</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Break dates:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 vs. 1</td>
<td>Oct-01 *</td>
<td>Aug-02 *</td>
<td>Aug-02 *</td>
<td>Aug-02 *</td>
<td>Aug-02 *</td>
</tr>
<tr>
<td>1 vs. 2</td>
<td>Oct-08 *</td>
<td>Oct-08 *</td>
<td>Nov-08 *</td>
<td>Nov-08 *</td>
<td>Nov-08 *</td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>Jun-95 *</td>
<td>Jun-95 *</td>
<td>Jun-95 *</td>
<td>Jun-95 *</td>
<td>Jun-95 *</td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>May-15 *</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 vs 5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F-statistic:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 vs. 1</td>
<td>470.79</td>
<td>909.1812</td>
<td>967.2963</td>
<td>981.3271</td>
<td>985.0481</td>
</tr>
<tr>
<td>1 vs. 2</td>
<td>127.344</td>
<td>169.9601</td>
<td>171.8421</td>
<td>178.0455</td>
<td>187.7122</td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>63.45411</td>
<td>200.1616</td>
<td>207.8597</td>
<td>210.8634</td>
<td></td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>15.16187</td>
<td>5.371016</td>
<td>3.78747</td>
<td>2.57288</td>
<td></td>
</tr>
<tr>
<td>4 vs 5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Critical Values**:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 vs. 1</td>
<td>8.58</td>
<td>8.58</td>
<td>8.58</td>
<td>8.58</td>
<td>8.58</td>
</tr>
<tr>
<td>1 vs. 2</td>
<td>10.13</td>
<td>10.13</td>
<td>10.13</td>
<td>10.13</td>
<td>10.13</td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>11.83</td>
<td>11.83</td>
<td>11.83</td>
<td>11.83</td>
<td>11.83</td>
</tr>
<tr>
<td>4 vs 5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Significant at 0.05 level

** Bai-Perron (Econometric Journal, 2003) critical values

The first important thing to note is that the average inflation expectations for the shorter term present different breakpoints compared to the longer-term average expectations.
From a maximum number of 5 possible break points, the test suggests a total of 4 breaks for the one-year ahead inflation expectations and a total of 3 breaks for the five-, ten-, fifteen- and twenty-years ahead inflation expectations, significant at a 5% level.

For the one-year ahead expected inflation, the sequential break dates were: October 2001, October 2008, June 1995 and May 2015. For the five- years ahead expected inflation, the break dates were August 2002, October 2008 and June 1995. The expectations for the ten, fifteen and twenty-years, ahead all showed the same break dates: August 2002, November 2008 and June 1995. All break dates occurred in dates close to the especial events related to monetary policy announcements and during the forward guidance strategy period. However, especially for the shorter-term expectations, the break dates seem to precede both monetary policy announcements and change in monetary policy rates.

Moreover, analyzing the changes in the parameters, for the period between 2008 and 2015, the promise to keep interest rates low was not followed by an increase in inflation expectations, as the theoretical model would suggest. The estimated parameters fall during this period, as it is possible to see from the graph 5 bellow, where the results for the ten years ahead inflation expectations are plotted. In table 4, it is possible to see that in the last estimated breakpoint time, the mean for the inflation expectations ten-years ahead was reduced from 2.42% to 1.79%, a level below the inflation target of 2%. The same conclusion can be reach when analyzing the possible effects of the communication strategy of 2002, when signaling of low interest rates were not followed by increase in inflation expectations. The structural change suggested by the breakpoint of 1995, on the contrary, were in line with the theoretical framework, since the signaling of higher levels for the interest rates should lead to lower levels of expected inflation.

Graph 4 – Actual, Fitted and residuals from the estimation
Table 4 – Regression results for the BLS estimation of the ten-years ahead inflation against a constant

Sample: 1990M01 2019M12
Included observations: 360
Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks
Breaks: 1995M06, 2001M01, 2008M11
Selection: Trimming 0.15, Max. breaks 5, Sig. level 0.05

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990M01 - 1995M05 – 65 obs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.035252</td>
<td>0.000296</td>
<td>119.2931</td>
<td>0.0000</td>
</tr>
<tr>
<td>1995M06 - 2000M12 – 67 obs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.030465</td>
<td>0.000291</td>
<td>104.6690</td>
<td>0.0000</td>
</tr>
<tr>
<td>2001M01 - 2008M10 – 94 obs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.024254</td>
<td>0.000246</td>
<td>98.70097</td>
<td>0.0000</td>
</tr>
<tr>
<td>2008M11 - 2019M12 – 134 obs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.017929</td>
<td>0.000206</td>
<td>87.11209</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared 0.885225 Mean dependent var 0.025041
Adjusted R-squared 0.884258 S.D. dependent var 0.007003
S.E. of regression 0.002382 Akaike info criterion -9.230336
Sum squared resid 0.0002021 Schwarz criterion -9.187157
Log likelihood 1665.460 Hannan-Quinn criter. -9.213167
F-statistic 915.2394 Durbin-Watson stat 0.224169
Prob(F-statistic) 0.000000

While the results do not support the hypothesis that the structural changes in inflation are related to the central bank’s signaling strategy, it also shows, in the case of the forward
guidance period, that the commitments to lower levels of interest rates did not create a time inconsistency problem, where the short-term goal of the expansionary policy could potentially conflict with the long-term goal of reaching the inflation targets.

5.3.2. Testing for structural changes in the Inflation expectations term structure

In the second model the test for structural changes in the inflation term structure. In order to capture the inflation term structure, a linear regression where the longer-term inflation expectation is the dependent variable, and the short-term inflation expectation is the independent variable. For the short-term inflation expectation, we used a measure for expectations for inflation one-year ahead. As for the long term, we tested models for expectations five-, ten-, fifteen-, and twenty-years ahead. The estimated regressor captures the covariance between the long-term and the short-term inflation expectations and can be interpreted as a measure of the inflation term structure. We then proceed to test for structural changes in the regressors. We estimate the same model for five, ten, fifteen and twenty inflation expectations. The test was also conducted within a sample that begins in January of 1990 and ends in December of 2019. The results are summarized in the table 5.

Table 5- Test for structural changes - Inflation Expectations Term Structure Slope

<table>
<thead>
<tr>
<th>Bai-Perron tests of L+1 vs. Sequentially determined breaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking Variables</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>Number of breaks</td>
</tr>
<tr>
<td>Break dates:</td>
</tr>
<tr>
<td>0 vs. 1</td>
</tr>
<tr>
<td>1 vs. 2</td>
</tr>
<tr>
<td>2 vs. 3</td>
</tr>
<tr>
<td>3 vs. 4</td>
</tr>
<tr>
<td>4 vs 5</td>
</tr>
<tr>
<td>Scaled F-statistic:</td>
</tr>
<tr>
<td>0 vs. 1</td>
</tr>
<tr>
<td>1 vs. 2</td>
</tr>
<tr>
<td>2 vs. 3</td>
</tr>
<tr>
<td>3 vs. 4</td>
</tr>
<tr>
<td>4 vs 5</td>
</tr>
<tr>
<td>Critical Values**:</td>
</tr>
</tbody>
</table>
From a total of five possible breakpoints, 4 breaks were identified using the Bai-Perron sequentially determined breaks test for inflation expectations. The only break date common for all the different durations was May 1995. The five-years ahead and the twenty-years ahead inflation expectations presented the same estimated break dates: November 2007, August 2002, May 1995 and May 2012. The ten and the fifteen-years ahead inflation expectations term yield also presented the same estimated set of break dates: March 2007, September 20000, September 2011 and May 1995. Although the break dates differ from the previous model specification, they are also consistent with special events in monetary policy announcements. In particular, the break dates for the 2011 and 2012, when specific promises about the future path of interest rates were made.

When we analyze the results of the regression including the breakpoints, the estimated coefficients were all positive and lesser than one. Taking the results for the regression of the ten-year inflation expectation against the one-year ahead, it is possible to observe a significant structural change in the relationship between the longer-term inflation expectation and the shorter term. From the results presented in table 6, we can observe that, after a increase in the coefficient estimated for the period between 1995 and 2002, when an increase of 1 percentage point in the expectation for inflation one-year ahead is followed by an increase of 0.61 percentage point, the subsequent breakpoints presented smaller coefficients. The coefficient estimated for the 2011 to 2019 period falls to 0.29.

The term structure can reflect the expected changes in business cycles, when the economic agents’ perception about the future can differ from the perception about the current conditions. The structural change in the term structure relationship of the inflation expectations towards a smaller coefficient can suggest either a perception of a smaller increments in inflation in the future in relation to the current and short-term inflation conditions (that can also be interpreted as a larger inflation increments in the present and immediate future in relation to the long-term expectations) or a better anchoring of inflation expectations around the targets in the long run. In either case, this evidence supports the
conclusions from the previous sections, and suggest that, in the periods where lower interest rates were signaled by the central bank, the commitments towards inflation targets remained credible.

Table 6 - Regression results for the BLS estimation of the ten-years ahead inflation against the one-year ahead inflation expectation and a constant
In Table 7 it is presented the summary of results when the Bai-Perron test for structural change is implemented for expectations over the real interest rates for different two time-periods ahead: one year and ten years. In this first model we consider only one breaking variable, as we did previously in section 5.3.1, a constant term that capture possible structural changes in the average real rate expectations for the two different time-periods ahead considered. The test is conducted for the same sample that begins in January of 1990 and ends in December of 2019.

Out of the 5 possible break dates, the total number of sequentially determined breaks were 4 for the one-year real rate and 3 for the ten-years real rate. However, only three were
statistically significant for both regressions. The break dates estimated for the shorter expected rate differs from the ones related longer rate. For the regression with one-year real rate as dependent variable, the sequentially determined breaks were: April 2009, September 2001 and January 2015. For the regression with the ten-years real rate as dependent variable, the sequentially determined breaks were: August 2002, December 2008, and June 1995.

Comparing the break dates from the model estimated for the expected real interest rates with the model of the same specification estimated for the inflation expectations, it is possible to conclude that the break dates for the variables are close, especially when we compare the ten-years ahead inflation with the ten-year expected real rate. In the case for the longer-term yield, the second estimated break date was identified at the beginning of the “forward guidance” strategy. However, other break dates related to specific commitments during the forward guidance period could not be identified.

Table 7 – Test for structural changes in Expected Real Interest Rates

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>One-year R.R.</th>
<th>Ten-years R.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking Variables</td>
<td>constant</td>
<td>constant</td>
</tr>
<tr>
<td>Number of breaks</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Break dates:
- 0 vs. 1: Apr-09 * Aug-02 *
- 1 vs. 2: Sep-01 * Dec-08 *
- 2 vs. 3: Jan-15 * Jun-95 *
- 3 vs. 4: non-sign. -
- 4 vs 5: - -

F-statistic:
- 0 vs. 1: 339.7829 918.1463
- 1 vs. 2: 100.6735 253.7692
- 2 vs. 3: 25.82349 109.9507
- 3 vs. 4: 10.87631 3.00493
- 4 vs 5: - -

Critical Values**:
- 0 vs. 1: 8.58 8.58
- 1 vs. 2: 10.13 10.13
- 2 vs. 3: 11.14 11.14
- 3 vs. 4: 11.83 11.83
- 4 vs 5: - -

*Significant at the 0.05 level
** Bai-Perron (Econometric Journal, 2003) critical values
period. As we can observe in the graph 5, after the estimated breakpoint of 2008, the average real interest rate was lower than the previous periods. From the regression results presented in the table 8, it is possible to observe that the estimated mean for ten-year forward real rate after the structural change of 2008 is 0.62%, less than half of the coefficient estimated for the previous period (1.88%). This reduction shows that the forward guidance strategy of signaling lower interest rates were followed by a reduction of expect real interest rates.

Graph 5 – Actual, Fitted and Residuals for the BLS regression of the ten-year real rate against a constant

![Graph showing residuals, actual, and fitted values over time.]

Table 8 – Regression results for the BLS estimation of the ten-year forward real rate against a constant

<table>
<thead>
<tr>
<th>Year</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>-0.015</td>
</tr>
<tr>
<td>92</td>
<td>-0.010</td>
</tr>
<tr>
<td>94</td>
<td>-0.005</td>
</tr>
<tr>
<td>96</td>
<td>0.000</td>
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<tr>
<td>98</td>
<td>0.005</td>
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<tr>
<td>00</td>
<td>0.010</td>
</tr>
<tr>
<td>02</td>
<td>0.015</td>
</tr>
<tr>
<td>04</td>
<td>0.020</td>
</tr>
<tr>
<td>06</td>
<td>0.025</td>
</tr>
<tr>
<td>08</td>
<td>0.030</td>
</tr>
<tr>
<td>10</td>
<td>0.035</td>
</tr>
<tr>
<td>12</td>
<td>0.040</td>
</tr>
<tr>
<td>14</td>
<td>0.045</td>
</tr>
<tr>
<td>16</td>
<td>0.050</td>
</tr>
<tr>
<td>18</td>
<td>0.055</td>
</tr>
</tbody>
</table>
5.3.4. Testing for structural changes in the real rate term structure

The real rate term structure is also analyzed for possible structural changes that could be related to the central bank strategy for managing expectations. To capture the real term structure, a linear regression is estimated, where the longer-term real rate is the dependent variable, and the short-term real rate is the independent variable. The estimated regressor captures the covariance between the long-term and the short-term real interest rate. For this model we consider three different regressions. We estimate the same model for three different real rate yields. In the first regression, a short-term yield in which the dependent variable is the one-year real rate, and the independent variable is the one-month rate. The second regression, we estimate the relation between the ten-years real rate and the one-month real rate. In the last, the ten-year real rate and the one-year real rate were considered. The same sample that begins in January of 1990 and ends in December of 2019 was used. The results for Bai-Peron test for break dates are summarized in the table 9.

<table>
<thead>
<tr>
<th>Sample: 1990M01 2019M12</th>
<th>Included observations: 360</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks</td>
<td></td>
</tr>
<tr>
<td>Breaks: 1995M06, 2001M01, 2008M12</td>
<td></td>
</tr>
<tr>
<td>Selection: Trimming 0.15, Max. breaks 5, Sig. level 0.05</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990M01 - 1995M05 -- 65 obs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.035960</td>
<td>0.000536</td>
<td>67.15111</td>
<td>0.0000</td>
</tr>
<tr>
<td>1995M06 - 2000M12 -- 67 obs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.029888</td>
<td>0.000527</td>
<td>56.66574</td>
<td>0.0000</td>
</tr>
<tr>
<td>2001M01 - 2008M11 -- 95 obs</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.018759</td>
<td>0.000443</td>
<td>42.34896</td>
<td>0.0000</td>
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<tr>
<td>2008M12 - 2019M12 -- 133 obs</td>
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<td></td>
</tr>
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<td>C</td>
<td>0.006168</td>
<td>0.000374</td>
<td>16.47705</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared 0.879678  Mean dependent var 0.019284
Adjusted R-squared 0.878664  S.D. dependent var 0.012394
S.E. of regression 0.004317  Akaike info criterion -8.041290
Sum squared resid 0.006636  Schwarz criterion -7.998111
Log likelihood 1451.432  Hannan-Quinn criter. -8.024121
F-statistic 867.5781  Durbin-Watson stat 0.205954
Prob(F-statistic) 0.000000
Table 9 – Test for structural changes on Real Rates Term Structure

Bai-Perron tests of L+1 vs. Sequentially determined breaks

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>One-year R.R</th>
<th>Ten-year R.R.</th>
<th>Ten-year R.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking Variables</td>
<td>One-month R.R.</td>
<td>R.R.</td>
<td>One-year R.R.</td>
</tr>
<tr>
<td>Constant</td>
<td>Constant</td>
<td>Constant</td>
<td>Constant</td>
</tr>
<tr>
<td>Number of breaks</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Break dates:

<table>
<thead>
<tr>
<th></th>
<th>One-month R.R.</th>
<th>Constant</th>
<th>Ten-year R.R.</th>
<th>One-year R.R.</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 vs. 1</td>
<td>Aug-01</td>
<td>*</td>
<td>Aug-02</td>
<td>*</td>
<td>Jun-05</td>
</tr>
<tr>
<td>1 vs. 2</td>
<td>Apr-09</td>
<td>*</td>
<td>Nov-08</td>
<td>*</td>
<td>May-95</td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>Aug-95</td>
<td>*</td>
<td>May-95</td>
<td>*</td>
<td>Jul-10</td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>May-15</td>
<td>-</td>
<td>-</td>
<td>Dec-00</td>
<td>*</td>
</tr>
<tr>
<td>4 vs 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jun-15</td>
</tr>
</tbody>
</table>

Scaled F-statistic:

<table>
<thead>
<tr>
<th></th>
<th>One-month R.R.</th>
<th>Constant</th>
<th>Ten-year R.R.</th>
<th>One-year R.R.</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 vs. 1</td>
<td>220.3141</td>
<td></td>
<td>588.4759</td>
<td>380.6315</td>
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</tr>
<tr>
<td>1 vs. 2</td>
<td>55.56974</td>
<td></td>
<td>187.0842</td>
<td>205.1667</td>
<td></td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>43.09805</td>
<td></td>
<td>266.4346</td>
<td>176.438</td>
<td></td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>47.72431</td>
<td></td>
<td>2.584945</td>
<td>28.11502</td>
<td></td>
</tr>
<tr>
<td>4 vs 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.0966</td>
</tr>
</tbody>
</table>

Critical Values**:

<table>
<thead>
<tr>
<th></th>
<th>One-month R.R.</th>
<th>Constant</th>
<th>Ten-year R.R.</th>
<th>One-year R.R.</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 vs. 1</td>
<td>11.47</td>
<td></td>
<td>11.47</td>
<td>11.47</td>
<td></td>
</tr>
<tr>
<td>1 vs. 2</td>
<td>12.95</td>
<td></td>
<td>12.95</td>
<td>12.95</td>
<td></td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>14.03</td>
<td></td>
<td>14.03</td>
<td>14.03</td>
<td></td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>14.85</td>
<td></td>
<td>14.85</td>
<td>14.85</td>
<td></td>
</tr>
<tr>
<td>4 vs 5</td>
<td>15.29</td>
<td></td>
<td>15.29</td>
<td>15.29</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

** Bai-Perron (Econometric Journal, 2003) critical values

Most break dates estimated for the different measures of the real rate term structure do not present similarities with one another. For the one-year to one-month covariance relation, the total of 4 estimated break dates were: August 2001, April 2009, August 1995 and May 2015. For the ten-year to one-month covariance relation, the total of 3 estimated break dates were: August 2002, November 2008 and May 1995. Lastly, the total of 5 estimated break dates for the ten-year to one year relation were: June 2005, May 1995, July 2010, December 2000 and June 2015. Although some of the break dates are close to important monetary policy signaling events, since different measures provide different results, it becomes difficult to determine the estimated structural change period. These results also provide noticeably distant dates to those estimated for the inflation term structure.

Table 10 - Regression results for the BLS estimation of the ten-year forward real interest rate against the one-month real rate and a constant
Similarly, to what we could observe regarding the inflation expectations term structure, we could observe a reduction in the coefficient that measures the real rate term structure. As we can see from table 10, the coefficient that measures the relationship between changes in the one-month real rate and the ten-year real rate decreased after the 2008 breakpoint. Even though it remained positive, the coefficient was only 0.08, indicating that the expected changes in real interest in the short run where larger than the changes in the long run. Considering that the short-term real rate remained negative for most of the period in the aftermath of the crisis while the long-term presented smaller decreases, as illustrated in graph 2, this result was expected. It also suggests that the central bank strategy may be more effective in keeping the short-term rates low in comparison to the long-term rates.
Conclusions

Considering that monetary policy operates under a rule-base model following an inflation targeting framework, where credibility is essential to its effectiveness, the role of central bank communication includes transparency and predictability. Central bank communication can also influence expectations about the future. Considering agents that are forward looking, expectations about inflation and the future path of interest rates over consumption and output can be an important transmission mechanism for monetary policy.

Even though the importance of communication and signaling has always been stressed under the inflation targeting framework, in the aftermath of the 2008 crisis, as the interest rates reached the zero-bound, it became systematically used as a monetary policy tool in many countries. As some central banks refused to implement negative interest rates, promises of future low interest rates were expected to keep the market rates down. Signaling strategies had been used before. In the United States, there are at least two documented events: the 1995 “irrational exuberance” signaling and the 2003 attempt to manage expectations as the nominal rates approached zero for the first time.

Theoretical models indicate that announcements about future changes in policy can affect asset prices in the present with transmission effects to the economy. Moreover, in the presence of large demand socks, the central bank can influence output and inflation through forward guidance, especially if monetary policy is restricted to a zero-bound on the interest rates. However, as the central banks attempts to manage expectations, committing to a lower level of interest rates and a higher level of inflation in the short run, they may face time inconsistency issues, since the short run expansionary goal can conflict with the long run commitment to the inflation targets.

Using a Bai-Perron model for identifying structural changes in linear model, this study tests and identifies break dates in both inflation expectations and expected real interest rates in the United States from 1990 to 2019. The breakpoints are related to structural changes in expectations that may be associated with changes in the central bank’s communication strategy. Since the Federal Reserve of Cleveland database was chosen for the empirical analysis, it is possible to perform the test for expectations over several different time horizons. It is also possible to test for breakpoints in the term structure for both inflation expectations and expected real rates.

Even though the evidence may support that the signaling strategy could have had an impact over inflation expectations and expected real interest rates, the causality is not clear. Some estimated break dates occurred in months prior to the signaling events. However, we found evidence that during the forward guidance period, that central bank communication strategy through public commitments of keeping the interest rates low for an extended period did not reduce its credibility in relation to the inflation targets, as the expected inflation remained below the targets. The strategy can also be associated with lower expectations regarding real interest rates. Nevertheless, it may be more effective in keeping the short-term real rates lower in comparison to the long run.


