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BACHELOR'S THESIS

The Effectiveness of the Federal Reserve's Monetary Policy under the Zero Lower Bound

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Declaration of Authorship

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Prague, July 31, 2017

Signature

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List of Abbreviations

ZLB Zero Lower Bound

Fed Federal Reserve System

LSAP Large Scale Asset Purchases

QE Quantitative Easing

CPI Consumer Price Index

PPI Producer Price Index

ISM Institute for Supply Management

GDP Gross Domestic Product

OLS Ordinary Least Squares

bp basis points

Bachelor's Thesis Proposal

Author	Lukáš Petrásek
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Proposed topic	The Effectiveness of the Federal Reserve's Monetary Policy under the Zero Lower Bound

Research question and motivation In response to worsening economic conditions, many central banks around the world have lowered their policy rates to levels at or near zero. Some parts of economic theory suggest that at rates close to the zero lower bound, monetary policy loses some or even all of its effectiveness (Woodford, 2011). However, as Swanson & Williams (2014a;b) showed, in 2012, after the policy rates had been at or near their effective zero lower bound for 4 years, there had still been room for the Fed, ECB, and the Bank of England to affect the interest rates through monetary policy. The explanation is that the entire path of expected future short-term interest rates plays the key role, not just the current short-term interest rate (Woodford, 2003). This implies that central banks can still influence the economy by managing expectations. My task will be to examine how the ability of the Fed, ECB, the Bank of England, and possibly Czech National Bank and Swiss National Bank (if the data will be available and sufficient) to influence interest rates evolved over the period with zero lower bound, most importantly in the recent 4 years which is a period not covered by Swanson & Williams (2014a;b). Research in this area is much needed in order for economists and especially policymakers to understand the effects of the zero lower bound which is a new factor in the economic environment.

Contribution The contribution of my thesis consists of an update in Swanson and Williams' work which covers only a period ending in 2012. In addition, I will control for a few other factors, such as trend or systemic stress, in the regressions. Next, if the data will be available and sufficient, I will apply the methods used in Swanson & Williams (2014a;b) for the case of the Czech Republic and Switzerland. The results should provide valuable information not only about the effectiveness of monetary

policy, but also about the possible size of the fiscal multiplier, an important element in fiscal policy.

Methodology I will use data for the bond yields (of various maturities), realized and expected values of various macro data announcements, systemic stress, and possibly other factors. I will apply the existing method proposed in Swanson & Williams (2014a). I will begin by separating the surprise component of several macro data announcements important for the US, UK, German, and possibly Czech and Swiss economies. I will do that by subtracting the expectation of the value of individual data release from their actual (realized) value. Secondly, I will use the OLS method to estimate the sensitivity of bond yields to those surprise components over the period from 1990 to 2016 (the beginning of the period will depend on the data available). I will use a similar regression to the one used in Gürkaynak *et al.* (2005), but I will control for other factors, such as trend or systemic stress. Lastly, I will compare the sensitivity of bond yields from the period where most policy rates were at or near the effective lower bound (usually a period from late 2008 to 2016) with the sensitivity which prevailed up until 2008 (which is considered to be a period where the sensitivity was normal). Periods in which the zero lower bound has been binding (partially or completely) should appear as periods in which the sensitivity of bond yields has been unusually low. This comparison will be achieved by running rolling regressions.

Outline

1. Introduction - theoretical background
2. Data - description of the data
3. Methodology - empirical framework
4. Results and Further Issues - discussion of results, further issues, comments
5. Conclusion - summary of the thesis

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Chapter 1

Introduction

In the wake of the 2008 global financial crisis, as a response to bad economic conditions, many central banks decided to cut their monetary policy rates down to essentially zero in order to boost the economy. However, a part of the nature of an interest rate is that it can hardly be pushed further below the levels around zero. The particular level of this constraint, the so-called zero lower bound (ZLB), generally differs for each economy, and it does not necessarily have to be equal to zero.[1] And because the floor on the interest rates may be somewhat above or below zero, we sometimes speak of the effective zero lower bound.[2]

During normal times, when the interest rates are above zero, a typical central bank uses mainly a very short-term interest rate to influence economic behavior. Therefore, at the ZLB, the economy's central bank loses its principal instrument of monetary policy. Accordingly, some authors, e.g. Borio & Hofmann (2017), or Walsh (2009), argue that such a central bank may lose a significant part (if not all) of its monetary policy effectiveness. There is a substantial body of literature which investigates the ZLB effect on the monetary policy. The researchers typically support the view that the presence of the zero bound causes monetary policy to be less effective, but, as some authors also add, it does not necessarily imply that the central bank cannot conduct monetary policy anymore.[3] See, e.g., Swanson & Williams

[1] This could be e.g. due to institutional reasons, see Bernanke & Reinhart (2004), or Swanson & Williams (2014b) .

[2] The terms zero lower bound, ZLB, effective zero lower bound, effective lower bound, or just zero bound, are used interchangeably throughout this text.

[3] As we will show later, it still has other tools for such purposes, e.g. forward guidance or quantitative easing. We will provide an overview of some conventional and unconventional monetary policy instruments in Chapter 2.

(2014a;b), Moessner (2014), Moessner *et al.* (2016), and a number of other studies in the literature review provided below.[4]

It is generally accepted that longer-term interest rates are highly important for the economic activity, if not even more important than short-term rates, and that medium-term and long-term interest rates are, in this respect, more relevant than the current policy rate, see e.g. Turner (2013), Moessner *et al.* (2016), or Swanson & Williams (2014a;b). The longer-term interest rates are determined by the path of expected short-term interest rates. Thus, apart from the option of influencing the long-term interest rates directly, using e.g. quantitative easing, the monetary authority can manipulate them through changes in the expectations of future short-term interest rates. Eggertsson & Woodford (2003), Moessner *et al.* (2016), or Swanson & Williams (2014a) assert that virtually any action taken by the central bank which has the power to alter these expectations can be considered as a potential monetary policy instrument.[5] Therefore, even when the policy rate cannot be pushed below the effective ZLB, there may still be room for the central bank to conduct monetary policy at least through managing expectations.

Our goal is to examine the ability of the central bank to conduct monetary policy under the zero lower bound in the case of the United States. Therefore, the monetary authority in the center of our analysis will be the Federal Reserve System (commonly called the Fed).

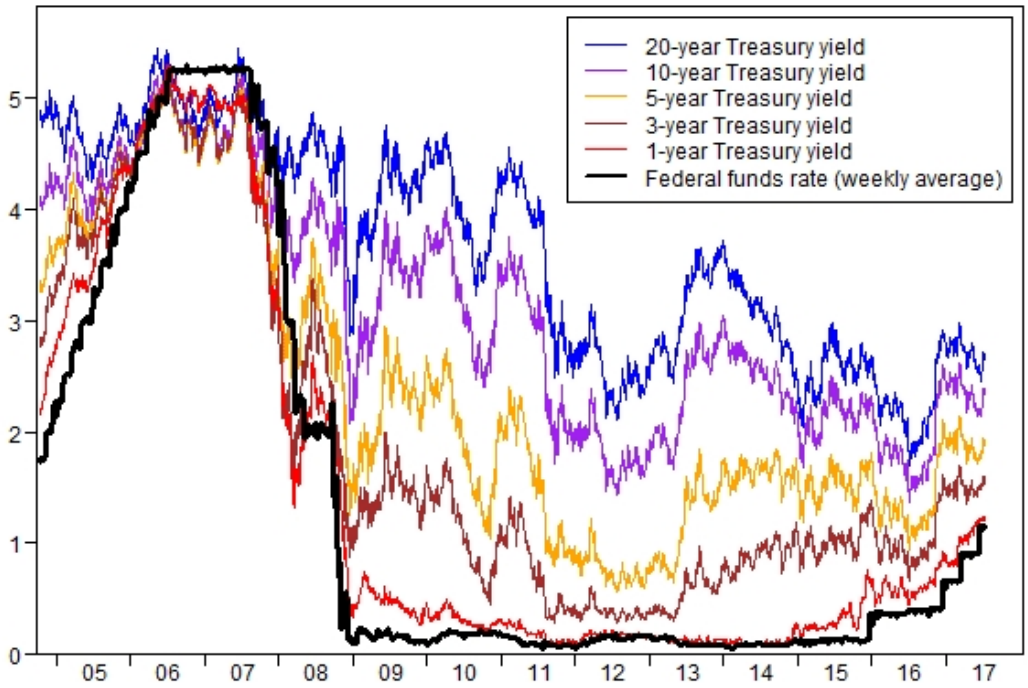
In late 2008, in order to pursue the Federal Reserve's statutory objectives for monetary policy, i.e. stable prices and low unemployment, the Federal Open Market Committee, a body which oversees the Fed's open market operations, cut the federal funds rate down to essentially zero. Figure 1.1 shows the development of the federal funds rate, as well as interest rates of longer maturities, following late 2004. Since there was no room for the further use of its policy rate, the Fed sought other ways to stimulate the economy.

In 2009 the Federal Reserve System initiated the first round of

[4]Swanson & Williams (2014a), and Moessner (2014) estimate the sensitivity of Treasury yields on surprises in macroeconomic news. They find that short-term yields were constrained in the presence of the effective lower bound, but the sensitivity of longer-term yields was unaffected. They interpret the sensitivity of bond yields to news as a measure of monetary policy effectiveness and conclude that the Federal Reserve System was essentially unconstrained in the conduct of its monetary policy under the ZLB to the extent that it was able to influence longer-term interest rates. In this work, we follow their interpretation.

[5]Rosa (2016) assesses the impacts of more than 2200 various Federal Reserve System events on Treasury yields, stock prices, and exchange rates. He finds that the important events significantly influence financial markets.

Figure 1.1: Federal funds rate and Treasury yields



Notes: Both federal funds rate and Treasury yields in %.
Source: Federal Reserve System (1954–2017)

quantitative easing. In total, there were three rounds during which the Fed's balance sheet grew by more than $2.5 trillion in size Labonte (2017). The Fed also launched its maturity extension program under which it extended the maturity of the Treasury securities it held. Moreover, the Fed has increasingly relied on communication since the crisis Doh & Connolly (2013). As we will explain below, it has used various forms of forward guidance to help the economic actors in shaping their expectations about future monetary policy. Beginning in 2012, the Federal Reserve began to provide a so-called data-based forward guidance. Since December 2015, when the federal funds rate target was increased for the first time after 7 years, it has been raised 3 more times and its upper bound is currently set to 1.25%.

Over the course of the last 10 years, Fed has accumulated a vast amount of assets. As the state of the economy returns back to normal, the central bank's monetary policy should return to normal as well. This monetary policy normalization requires a certain plan of actions, which has been referred to as the exit strategy. Finding an ideal exit strategy has lately been a big challenge in central banking. Hummel (2014) considers the options the Fed has with

regard to its exit strategy. Foerster (2015), or Berentsen *et al.* (2016) examine the effects of different exit strategies on the economy.[6]

The objective of our research is to investigate whether the Fed lost its ability to conduct monetary policy during the period of low interest rate environment, or whether the ZLB was not binding enough to impair such an ability.[7] Above else, the results of this work may help economists and monetary policymakers to better understand the effects of the zero lower bound on the effectiveness of monetary policy.

This work is largely inspired by Swanson & Williams (2014a) who quantify the severity of the monetary policy constraint due to the effective lower bound in the United States by estimating the time-varying sensitivity of interest rates to surprises in macroeconomic news, and find that the 3-month and 6-month interest rates were severely constrained during the period of the ZLB ending in 2012, 1-year and 2-year rates were partially constrained, but 5-year and 10-year rates were not constrained at all during this period. Likewise, Moessner (2014), whose sample ends in 2013, conducts a similar analysis for the economies of Canada, the United Kingdom, and the United States, and finds that the 1-year Treasury yields' sensitivity to macroeconomic news was reduced by 65% during the ZLB period, 2-year yields' sensitivity fell by 46%, but the 5-year and 10-year yields were unconstrained. These results suggest that Federal Reserve's ability to carry out monetary policy was not impaired prior to 2012 or 2013, respectively, provided that the Fed could affect longer-term interest rates. The results of Huang (2015), who uses a different methodology, suggest that the ZLB attenuates the bond market responses to macroeconomic news. Moessner *et al.* (2016) adapted the approach of Moessner (2014) to analyze the impact of the ZLB and Swedish central bank's quantitative forward guidance on Swedish economy.

Most of the recent studies focused on the effects of monetary policies in particular. Gagnon *et al.* (2011) assert that the Federal Reserve's asset purchases led to substantial and long-lasting reduction in interest rates.

[6] See also English *et al.* (2015), Blinder *et al.* (2016), Mishkin (2011), or Bean *et al.* (2010) who carefully discuss topics such as the current monetary policy, the challenges it faces, or provide opinions on how the future of monetary policy will look.

[7] Let us make clear that the Fed may still be able to conduct monetary policy even when the sensitivity of interest rates to news is partially, but not completely, attenuated. If the interest rates are at least somewhat responsive to macroeconomic news, the monetary policy is, in the worst case, less effective in a sense that its impacts are lower. Alternatively, it is less efficient because it is then more costly to produce the same results. However, if the central bank is willing to expend enough resources, it can still be able to provide stimulus to the economy.

Similarly, Krishnamurthy & Vissing-Jorgensen (2011) find that the first two rounds of quantitative easing lowered interest rates. Reduction in both Treasury and corporate bond yields due to stimulative monetary policy is reported also in Wright (2012). Moessner (2013) focuses specifically on the Fed's policy rate forward guidance and finds that it has reduced the interest rates most effectively at the horizons of 4 and 5 years. Carvalho *et al.* (2016) conclude that, under the zero lower bound, the shorter-term yields respond less to Fed's communication, however, it still has room for the conduct monetary policy through affecting longer-term yields. See also Meinusch & Tillmann (2016) and Christensen & Rudebusch (2012), who claim that Fed's large scale asset purchases (LSAP) affect interest rates, the latter article highlights that the effect is achieved primarily through lower expectations of future short-term rates, and Hamilton & Wu (2012) who study the effects of unconventional monetary policies on yields.

Rather than aiming only at the effects on the yield curve, some authors also estimate other effects on financial markets. Recently, Swanson (2017) finds substantial influence of both LSAP and forward guidance on medium-term Treasury yields, stock prices, and even exchange rates. He concludes that, under the ZLB, large scale asset purchases were a more effective monetary policy instrument than forward guidance. Doh & Connolly (2013) maintain that the responses of asset prices on communication weakened during the period of the lower bound on Fed's policy rate. See also Wu (2016), who estimates the impacts of monetary policy shocks on stock prices, corporate bond yields, and Treasury yields, and finds that the market with short-term Treasury securities is severely constrained by the ZLB, while the long-term government bonds are responsive to news throughout the entire sample period from 1990 to 2012.

There are also studies that attempt the estimate the policy impacts on the economic activity under the ZLB. Wu & Xia (2016) state that the Fed's post-crisis policies caused a meaningful reduction in the unemployment rate. Gambacorta *et al.* (2014) conduct a cross-country analysis of the effects of unconventional policies on the economy, and find that exogenous increases in central banks' balance sheets promote economic activity and increase consumer prices.

To summarize it, the existing literature mostly promotes lower effectiveness of monetary policy under the zero bound as authors generally find reactions of interest rates or asset prices to monetary policy or macroeconomic news to be partially, but not completely attenuated. It is

often the case that the sensitivity of short-term interest rates becomes attenuated under the ZLB, medium-term rates are partially responsive, and long-term rates are completely unconstrained. The results suggest that as long as the Fed can influence longer-term interest rates, it is able to conduct monetary policy. We intend to contribute to the existing body of knowledge by estimating the sensitivity of Treasury yields to macroeconomic news and thus evaluating the severity of the constraint that the effective zero lower bound puts on the Fed's ability to conduct monetary policy.

The main purpose of this thesis is to update the work of Swanson & Williams (2014a), and Moessner (2014) who estimate the sensitivity of Treasury yields to macroeconomic news. However, their sample periods end in 2012, and 2013, respectively. Above else, our contribution rests in prolonging the sample to late 2015, so that it covers the whole period during which the federal funds rate was at its effective zero lower bound.[8]

We also provide a different methodology to obtain the estimates of the severity of the ZLB. We estimate the impacts on interest rates caused by surprising macroeconomic news. Compared to the approach used in Swanson & Williams (2014a), our method allows the sensitivity of individual indicators to be reduced, or enhanced more, relatively to other coefficients, between the periods of high and low interest rate environment. Swanson & Williams (2014a) assume that the relative magnitude of coefficients on those indicators is constant in time. We will later discuss this feature in light of the results of our analysis and suggest that the assumption made by Swanson & Williams (2014a) may be incorrect. Moreover, we work with a more diverse set of maturities of the yields that we use in our analysis. Compared to Swanson & Williams (2014a) we also add two more macroeconomic indicators as variables in the regression equation, namely average hourly earnings and building permits.

As was hinted above, there are reasons to think that the ZLB greatly impairs the ability of monetary authorities to carry out monetary policy, as well as arguments that support only moderate constraints. This work is intended to produce results which will help to reveal which of these arguments are stronger and what is the actual severity of the impact of the zero lower bound. In Chapter 5, we will present our results and compare them more closely with those of Swanson & Williams (2014a), and especially Moessner (2014), because the approach in these studies is very similar to ours. To preview those results,

[8]None of the works cited above covers the whole ZLB period.

they generally support the findings in existing literature that the shorter-term interest rates were constrained by the zero lower bound, but the longer-term interest rates remained unconstrained. The conclusion is that to the extend that the Fed is able to affect those longer-term yields, its monetary policy effectiveness was essentially unaffected by the presence of the zero lower bound.

The thesis is structured as follows. Firstly, theoretical background is laid in Chapter 2 by an introduction of several concepts relevant to the topic. Secondly, we set out the empirical framework of the thesis in Chapter 3. Chapter 4 describes the data and their characteristics. In Chapter 5 we present our results and provide a discussion of their implications. Lastly, **??** concludes with a summary of the thesis.

Chapter 2

Theoretical background

The essential purpose of this chapter is to briefly describe the potential channels through which central banks conduct monetary policy, then show how does the ZLB complicate the matter, to eventually demonstrate that the problems associated with the zero bound can be overcome. However, let us assert that this thesis attempts to assess the effectiveness of monetary policy in general, regardless of which tool does the monetary authority use to pursue its objectives.[1]

The institution responsible for the conduct of monetary policy in the United States is the Federal Reserve System. It uses various instruments to influence the money supply and interest rates to secure stable prices and maximum employment. In what follows, we introduce the main policy instruments available to the Fed. Labonte (2017) provides a good overview of the Fed's recent activities and policies including the description of its policy instruments on which we largely base the following part of this thesis.[2]

[1]To avoid confusion, let us briefly discuss what we mean by the effectiveness of monetary policy. In Chapter 5 we inspect the reactions of interest rates to surprises in macroeconomic news and when these reactions are not found to be constrained, we maintain that the monetary policy remains effective. However, one could argue that the Fed's statutory objectives for monetary policy are stable prices and low unemployment, and thus the monetary policy effectiveness should be measured rather by the effects on prices and unemployment. Although there is nothing wrong with the latter stance, throughout this text, whenever we speak of monetary policy effectiveness, we have in mind the capacity to influence interest rates. Clearly, when the effect on interest rates eventually translates to movements in inflation or unemployment rate, these two notions overlap, see Wu & Xia (2016) and Gambacorta *et al.* (2014).

[2]We also suggest the interested reader to address this paper for additional details.

2.1 Conventional tools of monetary policy

In normal times, the main objective of the Federal Reserve's monetary policy is the federal funds rate, its policy rate (see Figure 1.1). The Fed commonly uses open market operations as the primary channel through which it influences the federal funds rate, an interest rate at which depository institutions borrow or lend their reserve balances between themselves overnight. The federal funds rate in turn influences the levels of various longer-term interest rates in the economy (Labonte 2017). These operations take place on the secondary market for the Treasury securities. The Fed buys these securities to increase the money supply and decrease interest rates, or sells them to achieve the opposite.[3] As Labonte (2017) mentions, these operations are typically carried out by the use of repurchase agreements.

Secondly, the Fed sets the level of the reserve requirements which specify the fraction of the deposit liabilities a depository institution must hold as reserves. If the Fed wishes to increase the money supply and decrease interest rates, it can lower the reserve requirement, or vice versa. However, let us note that this instrument has not been used since 1992 (Labonte 2017).

The last of the Fed's main traditional instruments are the discount rate and the interest rates on required reserve balances and excess balances.[4] The discount rate is charged to depository institutions who borrow money from the Federal Reserve System. The latter two interest rates are paid on the required and excess reserves, i.e. they are paid to those who lend to the Fed. The level of the aforementioned interest rates is positively related to the level of the federal funds rate. These instruments have been used on a regular basis.

2.2 Unconventional tools of monetary policy

The aforementioned set of instruments consists of the so-called conventional instruments. In the wake of the recent financial crisis, the Fed decided to reduce the federal funds rate to nearly zero and so it reached the zero lower bound on its main instrument for the conduct of monetary policy. With no room for further cuts in its policy rate, the Fed had to seek other, unconventional, ways

[3] In our analysis, we use the yields on Treasury securities of several different maturities as measures of the level of interest rates in the economy. When the Fed decides to manipulate interest rates, the prices of government bonds and their yields are affected as well.

[4] The interest rate on required reserve balances and the interest rate on excess balances are two different, separately determined rates.

to further stimulate the economy.[5] With the short-term interest rates close to zero, the natural solution rests in the manipulation of longer-term rates. This rationale is supported by the evidence that economic decisions are determined by the entire path of expected future short-term interest rates rather than just by the overnight rate and that, in this sense, long-term interest rates are more important than short-term rates, see also Cromb & Fernandez-Corugedo (2004) for a more detailed discussion.

Ultimately, Fed decided to use mainly two channels through which to influence longer-term rates and hence, bypass the ZLB problem. It introduced large scale asset purchases and continued the active use of communication (the latter is also known as forward guidance).[6] In this section, we shortly present these two instruments.[7]

In late 2008, when the conventional tools were not available anymore, the Fed introduced large scale asset purchases in order to reduce longer-term interest rates and boost the economy. Also known as quantitative easing (QE), large scale asset purchases encompass the acquisition of agency debt, agency mortgage-backed securities, or Treasury securities on the secondary market. Until 2014, the Fed carried out three rounds of QE and also launched its maturity extension program referred to as Operation Twist. The maturity extension program involved selling shorter-term Treasury securities and simultaneously buying longer-term Treasury securities in order to cut longer-term interest rates. Quantitative easing results in higher prices of the purchased assets, which in turn decrease yields on those assets, to finally decrease the overall level of interest rates in the economy.[8] In addition, QE is

[5] See Doh & Choi (2016), or Wu & Xia (2016) for estimates of the shadow federal funds rate.

[6] The Federal Reserve has used forward guidance since May 1999 Campbell *et al.* (2012).

[7] These were not the only measures the Federal Reserve has taken to respond to the adverse circumstances after the onset of the recent financial crisis. As an immediate response to the worsening economic conditions, the Fed decided to take several actions to ease the threatening credit shortage. For example, it began to accept a larger variety of collateral and to provide liquidity to a wider group of recipients. It even used a very rare instrument of lending to non-banks which has not been used since the Great Depression (Labonte 2017). The Fed also provided direct support to specific institutions, namely to American International Group and Bear Stearns (Labonte 2017). However, these actions were intended as an instantaneous assistance to institutions in trouble in order to help them with liquidity issues rather than being constructed primarily to influence interest rates. Compared to the LSAP and forward guidance which were used to influence the interest rates and their expectations, these emergency measures were only of a temporary nature and were abandoned once the supported institutions recovered from the crisis. Consequently, we do not examine them more closely, because they are of a limited relevance for our analysis.

[8] Kiley (2016) and Wu (2016) find that monetary policy-induced movements in Treasury yields translate to changes in private yields.

typically accompanied by an increase in two important quantities, the first of which is the size of the central bank's balance sheet.[9] The second typically expanded quantity is the money supply, the increase of which also reduces interest rates.[10] On top of that, large scale asset purchases have substantial signaling effects inducing downward pressure on interest rates. There are various channels through which QE changes interest rates other than those mentioned above, an interested reader may refer to Krishnamurthy & Vissing-Jorgensen (2011) who investigate these channels.

As was already mentioned, all actions taken by monetary authorities which have the ability to alter the expectations of future interest rates can by regarded as instruments of their monetary policy. Therefore, communication is a fundamental monetary policy tool for central banks, especially in times when the ZLB constrains the policy rate. The higher are the reputation and the credibility of the central bank, the more effective is its communication, see e.g. Walsh (2009) for details. Many central banks have used this instrument particularly to form the economic actors' expectations about the central banks' future monetary policy strategy. Such specific use of communication by central banks is called forward guidance. Rather than making a commitment to the future monetary policy, central banks ordinarily use forward guidance to merely indicate their further actions, creating a space for discretion in their decisions. By an indication of future development of short-term interest rates, the central bank shapes the expectations of those rates, and thus forms the entire path of expected future short-term interest rates, which in turn determines the levels of current longer-term rates.

The forward guidance on policy rates takes many forms, the Federal Reserve adopted three of them in the past. Filardo & Hofmann (2014) provide an examination of various approaches to forward guidance and their effectiveness, we use their study to summarize the Fed's post-crisis use of forward guidance here. During the first years following the crisis, it used qualitative form of forward guidance, a form which lacks date or numerical thresholds regarding the suggested path of monetary policy. In 2011, the Fed began to include information about the expected time-frame of its monetary

[9] It may not be so e.g. in the case of a sale of shorter-term government bonds a purchase of longer-term government bonds at the same time, which is what Fed did under its maturity extension program, then the size of the balance sheet remains unchanged.

[10] When applying quantitative easing, the money supply, as measured by the monetary base, is increased by an expansion of bank reserves on the liability side of the Fed's balance sheet.

policy, pursuing the so-called calendar-based forward guidance. Since 2012, the Fed provided threshold-based forward guidance by replacing the date reference with a numerical threshold quantifying the conditions necessary for the central bank to take a particular action.[11] Altavilla & Giannone (2016) offer a detailed overview of the Fed's announcements regarding forward guidance and the LSAP.

2.3 Other theoretical foundations for our analysis

Swanson & Williams (2014a) propose a simple one-country model to qualitatively demonstrate how could the zero lower bound potentially influence the reactions of yields to news, i.e. central bank's ability to conduct monetary policy. They use a forward-looking investment saving curve to point out that if the ZLB constraint on the current short-term interest rates is binding, the severity of the constraint depends on the extent to which expectations of future short-term rates are constrained, and that in the extreme case, the economy might be essentially unaffected by the zero bound. They model inflation using a Phillips curve, longer-term yields using the expectations hypothesis and assume a Taylor rule for monetary policy. They calculate impulse and instantaneous responses of interest rates to an output shock.[12] The model implies that in the presence of the ZLB, all yields, regardless of their maturity, are less sensitive to news than in the period of high interest rate environment and that the shorter is the maturity of a particular yield, the more limited are its reactions to news.[13]

To conclude this chapter, while there are arguments in favor of a reduced effectiveness of monetary policy in times when the policy rate cannot be reduced more, we can also find ways how the central banks can bypass the ZLB problem. In what follows, we develop a framework which allows us estimate the severity of the ZLB constraint.

[11] More specifically, the Fed declared that it will keep the federal funds rate low until the unemployment rate falls below 6.5%, under the assumption that the inflation rate is less than 2.5%. In 2014, when the unemployment rate approached the threshold of 6.5%, the Fed removed the threshold from its statements, because it preferred to keep interest rates low a little longer without breaking its pledge (Labonte 2017).

[12] Swanson & Williams (2012) calculate impulse and instantaneous responses of interest rates to both output and inflation shocks.

[13] Swanson & Williams (2014b) work with an alike model to demonstrate similar consequences for yields and exchange rates in a two-country example.

Chapter 3

Empirical framework

In the previous chapter we introduced several concepts relevant to our topic. Now we develop an empirical framework with which we later analyze the extent to which the ZLB constrains Treasury yields of various maturities. We will begin by introducing the explanatory variables we use in our regressions. Then we will specify the regression equation and discuss some further matters related to our methodology.

3.1 Explanatory variables

In order to capture the sensitivity of interest rates to macroeconomic news we initially follow Gürkaynak *et al.* (2005) and Swanson & Williams (2014a;b). Theoretically, financial markets should incorporate all relevant information prior to the release of macroeconomic news, therefore, the interest rates should react only to new, unanticipated, information contained in the data announcement. Thus, the first step in our empirical analysis is to identify the surprise components of all macroeconomic news releases in the dataset. We work with all the 12 indicators used in Swanson & Williams (2014a), and in addition we include two more to our dataset, namely average hourly earnings and building permits. We now briefly introduce all the macroeconomic indicators employed in the analysis.

Firstly, we present the so-called procyclical indicators. We use two measures of inflation, core consumer price index (CPI) and core producer price index (PPI), which do not take into account prices of food and energy. Next, we employ two figures providing information from the housing market, these are the new home sales and newly issued building permits. The data on

retail sales provide information about consumer spending, here we use those that exclude motor vehicles. Nonfarm payrolls reveal the change in the number of workers who were employed in a given month with respect to the preceding month, excluding those who work in agriculture. Consumer confidence quantifies the degree of optimism regarding the economic environment as perceived by consumers. We use two indices in our analysis, the Manufacturing Purchasing Managers Index compiled by the Institute for Supply Management (ISM), here referred to as the ISM Index, tracks manufacturing conditions and activity, and the Leading Economic Index (also known as leading indicators) is a composite index constructed from ten economically important indicators. Capacity utilization rate represents the fraction of installed production capacity employed. We also employ the annualized growth of the gross domestic product (GDP), and data on average hourly earnings of nonfarm employees.

Moreover, we use two countercyclical macroeconomic indicators which contain additional information from the labor market. The first measure is the unemployment rate. Secondly, initial jobless claims measure the number of people who applied for unemployment insurance for the first time in a given week.

The identification of the surprise components of these macroeconomic data releases is easily done by subtracting the expected value of an individual data release from its realized value when the data is published. To facilitate easier interpretation of the results, the surprise components are divided by their sample standard deviations, thus creating a series of normalized surprise components for each of the 14 macroeconomic indicators. Once we have obtained the surprise components from the announcement data, we can move ahead to estimate the sensitivity of the interest rates to macroeconomic news.

3.2 Regression equation

To estimate reactions of interest rates to surprise components of macroeconomic news, we continue to follow Gürkaynak *et al.* (2005) and Swanson & Williams (2014a;b). They regress daily changes in bond yields on the normalized surprise components of data releases that took place that day. The estimated regression takes the form

$$\Delta y_t^m = \beta_0^m + \sum_{i=1}^{14} (\beta_i^m * NSC_{i,t}) + \varepsilon_t^m \tag{3.1}$$

where t indexes days, Δy_t^m is the difference between the yield of a bond with maturity m on day t and on the day before, and $NSC_{i,t}$ is the normalized surprise component of the data release of the macroeconomic indicator i on day t, β_1,...,β_{14} are coefficients, and ε is a disturbance term. We use interest rates of 9 different maturities in our regression model. The maturities span a wide range from 3 months to 20 years. The regression equation is estimated by the Ordinary Least Squares (OLS) method.

The interpretation of the coefficients is straightforward. β_0 denotes the intercept, β_1,...,β_{14} are the estimated responses of the bond yield per one standard deviation surprise in the respective data release. We expect the coefficients on the procyclical indicators to be positive, and those on the countercyclical indicators to be negative, i.e. we expect the estimated response to a one standard deviation surprise in initial claims and the unemployment rate to be negative, and the responses of other variables to be positive.

We will tun the regression in Equation 3.1 first for the period of high interest rate environment. We set this period so that it contains each day t when the federal funds rate target (or the upper bound of the target range) is less than or equal to 0.25%. That is, we set the end of this period to December 15, 2008. Our sample begins on October 13, 2004, therefore, the high interest rate environment period contains more than 4 years of data. The coefficients then represent a response per one standard deviation surprise during normal times, i.e. a period when the ZLB is not present in the economy.

To facilitate examination of the severity of the ZLB constraint, we estimate Equation 3.1 also for the period of low interest rate environment which is set to begin on December 16, 2008 and to end on December 14, 2015 when the federal funds rate target was increased for the first time since the crisis.

During the ZLB period, we expect the coefficients to have the same signs as they had during normal times. For the period of low interest rate environment, a coefficient close to zero would suggest that the yield does not react to surprises in the news on the respective macroeconomic indicator. When the value of a coefficient under the ZLB approaches the value of the coefficient corresponding to the same indicator from the period of high interest rates, the responsiveness of yields to news concerning that indicator likely did not change. Intermediate values represent partial reductions in sensitivities of those yields. From Swanson & Williams (2014a;b) we know that the sensitivity under the zero bound may sometimes be even higher in

magnitude than when the ZLB is not present in the economy. We do not expect the coefficients to take values significantly opposite to those we anticipate for them, i.e. we do not expect the coefficients on initial claims and unemployment rate to be significantly positive, and the values of the coefficients on the other macroeconomic indicators to be significantly negative.

Let us briefly discuss the qualities of this methodology with respect to other approaches. The methods in many papers listed above are often focused directly on particular policies. One useful feature of the approach used here is that it allows us to investigate how the ZLB constrains monetary policy regardless of which particular policy instrument is used by the central bank to influence interest rates.

When the federal funds rate cannot be reduced anymore, it may be tempting to use the level of the yield itself as a measure of the severity of the zero lower bound. But there are reasons why not to do so. For example, if the yield is actually constrained, then the level of this yield does not provide any quantifiable information on the degree to which the yield reacts less to macroeconomic news, i.e. the extent to which the ZLB is binding, see Swanson & Williams (2014a).

We add one more useful aspect which is in favor of our modelling choice. The approach of Swanson & Williams (2014a) assumes that the relative magnitude of the coefficients in Equation 3.1 does not change in time. In other words, they do not allow any individual indicator to become, relatively to other indicators, more or less relevant for the financial market participants in their sentiment regarding interest rates. An advantage of our approach is that the sensitivity of individual indicators may be reduced, or enhanced more, relatively to other coefficients, between the periods of high and low interest rate environment. We will later discuss this feature in light of the results of our analysis.

In this chapter, we presented a method of obtaining estimates of the sensitivity of interest rates of different maturities to surprises in macroeconomic news announcements. We introduced the variables used in our regression model and discussed some features of our approach. Nextly, we will introduce the data we use in our analysis.

Chapter 4

Data

In this short chapter, we introduce the data which we later use in our regressions.

For the purpose of estimating the regression Equation 3.1 we obtain the data available in the economic calendar on finance.yahoo.com. YahooâĘ™s source of expectations data is Thomson Reuters, the actual realized values of the macroeconomic announcements are taken directly from their source, which are typically government organizations.

The data were properly scrutinized for errors. In the sample, we found several minor flaws in the data such as wrong units of measurement or omitted decimal points, which we quickly corrected. Nextly, we observed tens of missing values. Generally, it was possible for us to retrieve those values directly from their sources. However, on several occasions, we were unable to do that. Thus, our sample contains in total 9 missing values from 8 days. These days are omitted from our analysis. Let us assert that we take only the most important number from each of the announcement reports, and that other information included in the announcement may also have an effect on changes in interest rates.

We obtained the data on Treasury yields (see Figure 1.1) directly from the Federal Reserve System. Although we searched thoroughly for any error in the yield data, we found none. Let us note that we transformed these data from percentages to basis points (bp). Of course, our sample excludes weekends and banking holidays when no data are announced.

Now we have established both the estimation method and the data we employ in our analysis. In the next chapter we present the results of our estimation and provide a short discussion on the robustness of the findings.

Chapter 5

Results

In the previous two chapters, we introduced the empirical framework and presented our dataset. Now we are allowed to estimate the sensitivity of the government bond yields to news, i.e. to evaluate the effectiveness of Fed's monetary policy. We first present the estimated reactions of bond yields to macroeconomic news during a period when the ZLB was not present in the economy. Then we will provide the reaction estimates for the ZLB period. Nextly, visualization of the results will be accompanied by further discussion of their implications and a short description of the robustness checks we made.

5.1 Interest rate sensitivity during normal times

We use the OLS method to estimate the equation Equation 3.1. We begin by running the regression for the period of high interest rate environment, i.e. for the period of 4 years from the beginning of our sample to late 2008, when the federal funds rate target was far above 0.25%. The number of observations in this period totals to 1042.

The complete results for all maturities are reported in Table 5.1, we will now discuss the most important findings. Let us repeat that whenever we observe the yield responses to be, generally, lower in magnitude, we suspect the effective lower bound to be partially or completely binding. Each column of Table 5.1 represents the results of estimating Equation 3.1 for a given maturity m. Each of the coefficients shows a response per one standard deviation surprise during normal times, i.e. a period when the ZLB is not present in the economy.

We inspected our models for the presence of both heteroskedasticity and

Table 5.1: Responses of Treasury yields to news during normal times

	Yield maturity								
	3-month	6-month	1-year	2-year	3-year	5-year	7-year	10-year	20-year
Average hourly earnings	1.30**	0.88**	1.20***	2.23***	2.48***	2.80***	2.40**	2.16***	1.76**
	(0.53)	(0.43)	(0.44)	(0.85)	(0.94)	(0.96)	(0.95)	(0.82)	(0.71)
Building permits	3.10	2.29*	2.08***	2.44**	2.38***	2.46***	2.24***	1.73**	1.21**
	(2.03)	(1.23)	(0.80)	(0.97)	(0.91)	(0.84)	(0.76)	(0.67)	(0.59)
Consumer confidence	0.72	1.63**	1.38**	0.62	1.01	0.19	-0.16	-0.47	-0.65
	(0.59)	(0.66)	(0.65)	(1.29)	(1.20)	(1.32)	(1.30)	(1.28)	(1.02)
Core CPI	0.43	1.08	0.97	1.00	1.35	1.52	1.81*	1.52*	1.50*
	(1.05)	(0.94)	(0.92)	(1.00)	(1.11)	(1.02)	(0.94)	(0.87)	(0.87)
Core PPI	-0.18	0.20	0.67*	1.12*	1.14*	1.29**	1.31**	1.27**	1.38***
	(0.45)	(0.39)	(0.40)	(0.64)	(0.60)	(0.58)	(0.59)	(0.55)	(0.46)
Capacity utilization	0.22	-0.57	0.83	2.85	2.71	2.86*	2.72**	2.22**	1.40
	(2.84)	(2.24)	(2.04)	(1.85)	(1.87)	(1.52)	(1.30)	(1.08)	(1.08)
GDP (advance)	-0.09	0.58	1.03	2.09	1.46	1.70	1.55	1.65	1.37
	(0.71)	(0.75)	(1.01)	(1.63)	(1.46)	(1.47)	(1.40)	(1.20)	(1.13)
Initial claims	-0.54	-0.90*	-1.35***	-2.00***	-2.07***	-1.86***	-1.73***	-1.60***	-1.49***
	(0.58)	(0.46)	(0.42)	(0.44)	(0.49)	(0.49)	(0.47)	(0.45)	(0.42)
ISM manufacturing index	1.08*	1.80**	2.23***	2.99***	2.84***	2.60***	2.45***	1.98***	1.73***
	(0.59)	(0.78)	(0.51)	(0.89)	(0.74)	(0.59)	(0.52)	(0.49)	(0.47)
Leading indicators	2.28	3.19	1.67	-0.41	-0.47	-0.98	-0.93	-0.89	-0.54
	(1.83)	(2.09)	(1.48)	(0.95)	(1.09)	(1.08)	(1.14)	(1.17)	(1.02)
Nonfarm payrolls	0.90	1.78**	2.56***	3.36**	2.91**	3.17**	2.90**	2.53**	2.34***
	(1.00)	(0.87)	(0.82)	(1.31)	(1.46)	(1.40)	(1.35)	(1.12)	(0.83)
New home sales	0.01	-0.04	0.39	0.95*	1.04*	0.94	0.98*	1.05**	1.07***
	(0.50)	(0.35)	(0.36)	(0.53)	(0.54)	(0.58)	(0.52)	(0.47)	(0.40)
Retail sales excluding autos	1.42**	1.43***	1.66***	2.68***	2.58***	2.57***	2.42***	2.00***	1.36*
	(0.68)	(0.44)	(0.50)	(0.86)	(0.76)	(0.82)	(0.82)	(0.77)	(0.79)
Unemployment rate	-1.42***	-0.97**	-1.61**	-3.66***	-3.43***	-3.44***	-3.18**	-2.78**	-2.29***
	(0.47)	(0.46)	(0.67)	(1.15)	(1.18)	(1.32)	(1.24)	(1.09)	(0.88)

Each coefficient represents a basis point per standard deviation response. ***, **, and * indicate significance at the 1%, 5%, and 10% level. Newey-West adjusted standard errors in parentheses. Constant terms are not shown in the table. See text for details.

serial correlation. The result was that we always strongly rejected both the homoskedasticity and the no serial correlation standard model assumptions. We solve these problems with the use of the Newey-West heteroskedasticity and serial correlation consistent standard errors. These errors are reported in parentheses below the coefficients estimates.[1] To the right from the coefficient estimates, ***, **, and *denote statistical significance at the 1%, 5%, and 10% level.

In the first column of Table 5.1 we present the results for the 3-month Treasury yield during the period of high interest rate environment. We can see that a one standard deviation surprise in average hourly earnings causes, on average, the 3-month yield to increase by 1.30 bp. The coefficient on average hourly earnings is statistically significant at the 5% level. On the other hand, for the same yield, a one standard deviation surprise in the unemployment rate is followed by a statistically significant reduction similar in magnitude. ISM manufacturing index and retail sales excluding motor vehicles also significantly increase interest rates, although the former only at the 10% level. There is one coefficient, the one on the advanced GDP estimate, which has an unexpected sign, it is, however, statistically insignificant.

For the case of the 6-month yield, the second column reveals, for example, that one standard deviation surprises in the ISM manufacturing index typically bring about a rise of 1.80 bp, or that the retail sales indicator continues to have about the same impact as it had on the 3-month yield. Again, we have two insignificant variables with unexpected signs, capacity utilization and new home sales. Overall, the statistical significance of the variables improved, with the exception of the unemployment rate, which is, however, still significant at the 5% level. There are four more significant coefficients, namely those on building permits, consumer confidence, initial claims, and nonfarm payrolls.

The results for 1-year Treasury yields are generally similar to those for the 6-month yield. We can see that both statistical and economic significance of the coefficients increased. This time, no variable, not even an insignificant one, causes the yield to move in an unanticipated direction. The effects on the 2-year yield follow these trends. In absolute value, the highest effect among all maturities is that of the unemployment rate on the 2-year Treasury yield, one standard deviation surprise in the announced unemployment rate causes

[1] In the process of computation of the Newey-West standard errors, we set the integer g to take values equal to the integer part of $4 * (\frac{n}{100})^{\frac{2}{9}}$, where n is the number of observations of the given regression.

the yield to fall by -3.66 basis points. Moreover, the largest positive coefficient is located in the fourth column of Table 5.1, too. On average, one standard deviation surprise in nonfarm payrolls increases the 2-year yield by 3.36 basis points.

The effects appear to stabilize on the medium- to longer-term maturities of 3 and 5 years with most of the variables keeping their significance. For the long-term maturities of 7, 10, and 20 years we generally observe a reduced magnitude of the coefficients. However, the responsiveness of those yields to news remains very high.

We now summarize the main findings from Table 5.1. With increasing maturity of the yields, the coefficients initially gain both statistical and economic significance. As we move to longer maturities, the yield sensitivity stabilizes, and finally it decreases moderately. Average hourly earnings, the ISM index, retail sales, and the unemployment rate keep their high significance through all maturities. Building permits, initial claims, or nonfarm payrolls are also very important in terms of effects on the yield curve. There are no examples of a statistically significant variable having an opposite than expected sign.

Taking into account the results in previous research, the number of insignificant coefficients is not surprising. The results in Table 5.1 are roughly comparable to the results in Swanson & Williams (2014a) and Moessner (2014). However, let us note that they estimate somewhat different regressions and their sample periods are different, too. We also estimated the regression using the exact same set of variables as in Swanson & Williams (2014a), but the results almost did not change.

5.2 Interest rate sensitivity under the zero lower bound

To facilitate examination of the extent to which the ZLB constrained the interest rates, we estimate the Equation 3.1 also for the period of low interest rate environment which is set to begin on December 16, 2008 and to end on December 14, 2015 when the federal funds rate target was increased for the first time after the crisis. Taken together, there are 1751 observations in the ZLB period.

Table 5.2 provides results obtained from estimating Equation 3.1 for the

Table 5.2: Responses of Treasury yields to news under the ZLB

	Yield maturity								
	3-month	6-month	1-year	2-year	3-year	5-year	7-year	10-year	20-year
Average hourly earnings	0.13	0.25**	0.36	0.87*	1.38**	1.98**	2.12***	1.94**	1.69**
	(0.11)	(0.13)	(0.24)	(0.52)	(0.62)	(0.79)	(0.81)	(0.76)	(0.71)
Building permits	0.07	-0.06	0.14	0.60**	0.90**	0.87*	0.71	0.41	0.10
	(0.14)	(0.12)	(0.12)	(0.30)	(0.42)	(0.52)	(0.56)	(0.55)	(0.57)
Consumer confidence	-0.13	0.00	0.02	0.42	0.44	0.60	0.76	0.76	1.15**
	(0.13)	(0.10)	(0.16)	(0.31)	(0.39)	(0.52)	(0.59)	(0.54)	(0.55)
Core CPI	-0.08	-0.05	0.13	-0.33	-0.47	-0.92	-1.33	-1.22	-1.02
	(0.13)	(0.13)	(0.20)	(0.50)	(0.67)	(0.92)	(1.00)	(0.96)	(0.77)
Core PPI	0.00	0.16	0.39*	0.75**	1.05**	1.33**	1.35**	1.51**	1.73**
	(0.10)	(0.14)	(0.22)	(0.35)	(0.46)	(0.59)	(0.63)	(0.68)	(0.76)
Capacity utilization	0.02	0.02	-0.05	0.08	0.21	-0.14	-0.28	-0.65	-0.68
	(0.14)	(0.14)	(0.16)	(0.32)	(0.40)	(0.59)	(0.64)	(0.64)	(0.62)
GDP (advance)	0.15	0.33	0.08	0.32	0.12	0.37	0.09	0.37	0.45
	(0.19)	(0.21)	(0.17)	(0.47)	(0.68)	(0.96)	(1.28)	(1.09)	(1.01)
Initial claims	-0.06	-0.08	-0.16**	-0.53***	-0.77***	-0.99***	-0.74**	-0.94***	-1.04***
	(0.06)	(0.06)	(0.07)	(0.14)	(0.19)	(0.27)	(0.35)	(0.28)	(0.29)
ISM manufacturing index	0.19	0.13	0.07	0.61	0.80	1.42**	1.79**	2.04***	2.06***
	(0.18)	(0.12)	(0.15)	(0.42)	(0.49)	(0.68)	(0.80)	(0.79)	(0.75)
Leading indicators	0.12	0.05	-0.05	0.25	0.70*	0.99**	1.11*	1.20**	1.00
	(0.14)	(0.16)	(0.12)	(0.28)	(0.37)	(0.50)	(0.57)	(0.59)	(0.64)
Nonfarm payrolls	0.32	0.54**	1.54***	3.59***	4.17***	4.99***	4.99***	4.20***	3.89***
	(0.20)	(0.23)	(0.42)	(0.97)	(0.90)	(0.79)	(0.71)	(0.67)	(0.69)
New home sales	-0.07	-0.06	0.06	0.12	0.15	-0.01	-0.07	0.20	0.38
	(0.17)	(0.19)	(0.18)	(0.43)	(0.65)	(0.84)	(0.94)	(0.83)	(0.77)
Retail sales excluding autos	-0.01	0.09	0.54***	1.10***	1.53***	2.17***	2.39***	2.31***	2.33***
	(0.11)	(0.15)	(0.18)	(0.29)	(0.38)	(0.50)	(0.57)	(0.56)	(0.52)
Unemployment rate	0.01	0.02	0.07	0.13	0.08	0.16	0.15	-0.03	-0.01
	(0.13)	(0.12)	(0.24)	(0.60)	(0.60)	(0.72)	(0.70)	(0.68)	(0.64)

Each coefficient represents a basis point per standard deviation response. ***, **, and * indicate significance at the 1%, 5%, and 10% level. Newey-West adjusted standard errors in parentheses. Constant terms are not shown in the table. See text for details.

period from late 2008 to late 2015. The interpretation of the results is the same as before. Now the coefficients represent reactions of yields to macroeconomic news during the zero lower bound period.

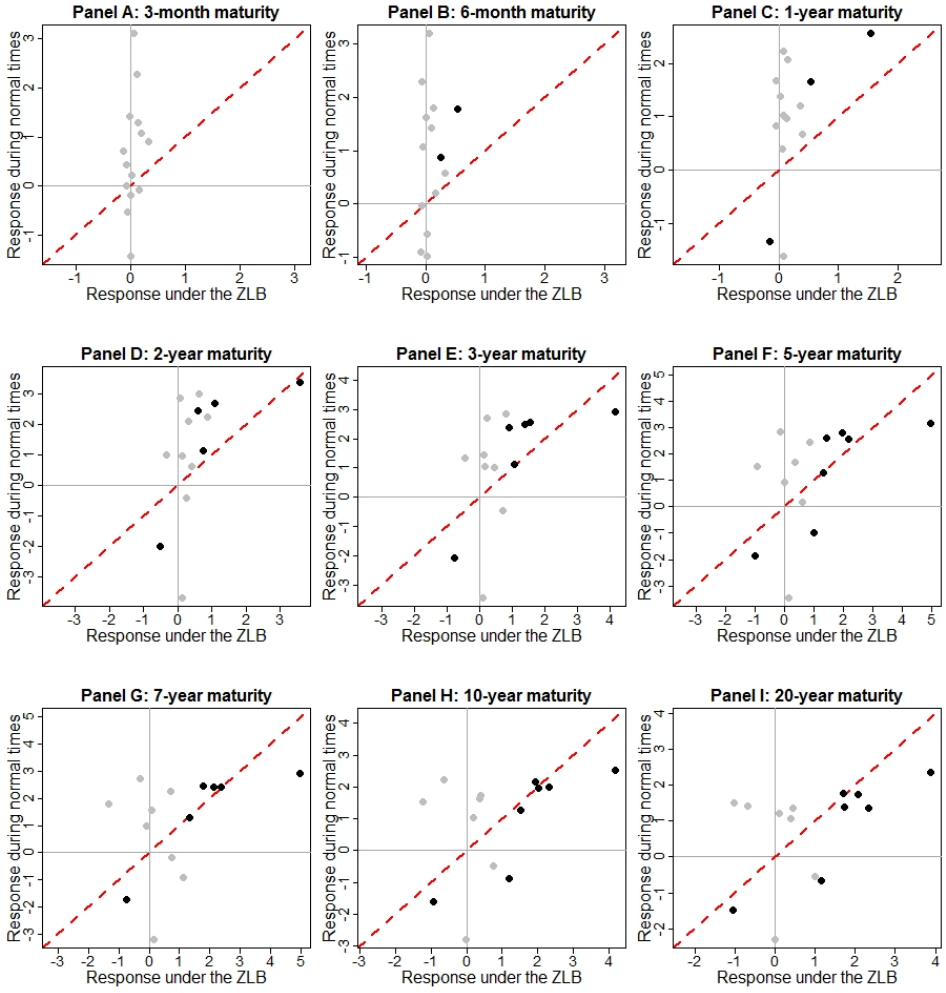
We immediately see that on the shorter end of the yield curve, the sensitivity to surprises in news appears to be meaningfully reduced. There are no significant responses estimated for the 3-month maturity, and even the significant responses of the 6-month yield tend to be very small. This finding suggests that the shorter-term Treasury yields were highly constrained by the zero lower bound. With increasing maturity, the severity of this constraint seems to fall as many indicators begin to have both statistically and economically significant impacts on yields. Similarly to the high interest rate environment results, we observe the longer-maturity yields reactions to news to be somewhat lower.

For higher maturities, some variables, e.g. core CPI or nonfarm payrolls, have even higher influence on interest rates than they had during normal times. Other indicators effects, e.g. that of the unemployment rate which was highly significant during the period of high interest rate environment, diminish. But because the yields respond to other news, we cannot say that this is caused purely by the overall sensitivity attenuation caused by the ZLB. It appears to be more likely that some variables become less relevant in explaining the movements in yields relative to other variables. This result suggests that the assumption of a constant relative magnitude of coefficients made in Swanson & Williams (2014a) and Moessner (2014) may be incorrect. Therefore, the results of the analysis in the aforementioned articles should be treated with more caution. Below we consider a graphical examination of this assumption.

5.3 Graphical presentation of the results

To better illustrate our findings, we prepared simple visualizations of the results. Firstly, we prepared charts with the sensitivity estimates under the ZLB on the x axis and the sensitivity from normal times on the y axis, see Figure 5.1. We now use this graphical presentation of our results to examine two issues. Firstly, to confirm our results that the shorter-term yields are rather constrained by the zero lower bound, while the longer-term rates typically are not. Secondly, we continue in our critique of the constant relative magnitude of coefficients assumption made in Swanson & Williams (2014a) and Moessner (2014).

Figure 5.1: Comparison of estimates from normal times and from the ZLB period



As a confirmation of our previous findings, consider Figure 5.1. It consists of 9 charts, one for each maturity, portraying the sensitivity estimates under the ZLB on the x axis and the sensitivity from normal times on the y axis. In the case of severe attenuation of the sensitivity of yields to macroeconomic news, the points in the chart should concentrate closely around the y axis, corresponding to zero sensitivity to these news. On the other hand, points which lie on the dashed red line with slope one belong to indicators that did not change their responsiveness to news in the presence of the zero lower bound with respect to normal times. When the point lies in the area between those lines, it is thought to be partially constrained. Indicators which were significant in the ZLB period have black color, insignificant estimates are represented by gray color.

Our results support the conclusions made in Swanson & Williams (2014a) and Moessner (2014) that the effectiveness of Fed's monetary policy under the zero bound was lower in terms of the ability to affect shorter-term interest rates, but at longer maturities, there was no evidence suggesting this effectiveness to be reduced. For shorter-term yields, the points are highly concentrated around the y axis, suggesting severe attenuation of the sensitivity to surprises in macroeconomic news. With higher maturities, the points eventually begin to move away from the y axis, suggesting lower or even no attenuation, which is the case of long-term maturities when the points move even behind the dashed red line.

Swanson & Williams (2014a;b) and Moessner (2014) argue that when the interest rates are constrained by the ZLB, the responsiveness to news is trimmed by about the same proportion for each type of macroeconomic data announcement. This means that for a one standard deviation surprise e.g. in Nonfarm Payrolls and the Consumer Price Index, the sensitivity of a particular bond yield should be reduced more or less by a proportional amount for both of these data announcements when the ZLB is binding. They claim that this result is quite intuitive as they find no obvious reasons for the market to react differently to different types of announcements when the ZLB constraints the bond yields. If this assumption was true, we should observe the points in Figure 5.1 to lie at least approximately on the same line going through the origin. Looking at the results, however, we find no support for this to be true. Instead, as we discussed above, our results suggest that this assumption is rather incorrect.

Secondly, we provide yet another set of charts which represent a different

visualization of our results. Figure 5.2 provides 14 panels, each depicts the relationship of the estimated coefficients from our results above and the yield curve. The black line represents the impacts during normal times, while the red line represents the impacts under the ZLB. 95% confidence intervals are portrayed be dashed lines. This visualization further demonstrates that the sensitivity of yields to surprising components of macroeconomic news is attenuated by the presence of the zero lower bound for the shorter maturities, while for longer maturities, the yields become less and less constrained. We might be concerned by the rather strange behavior of core CPI on panel D. However, the estimates of the effects of core CPI are statistically significant and therefore provide no meaningful evidence against the implications and conclusions we made above.

5.4 Robustness checks

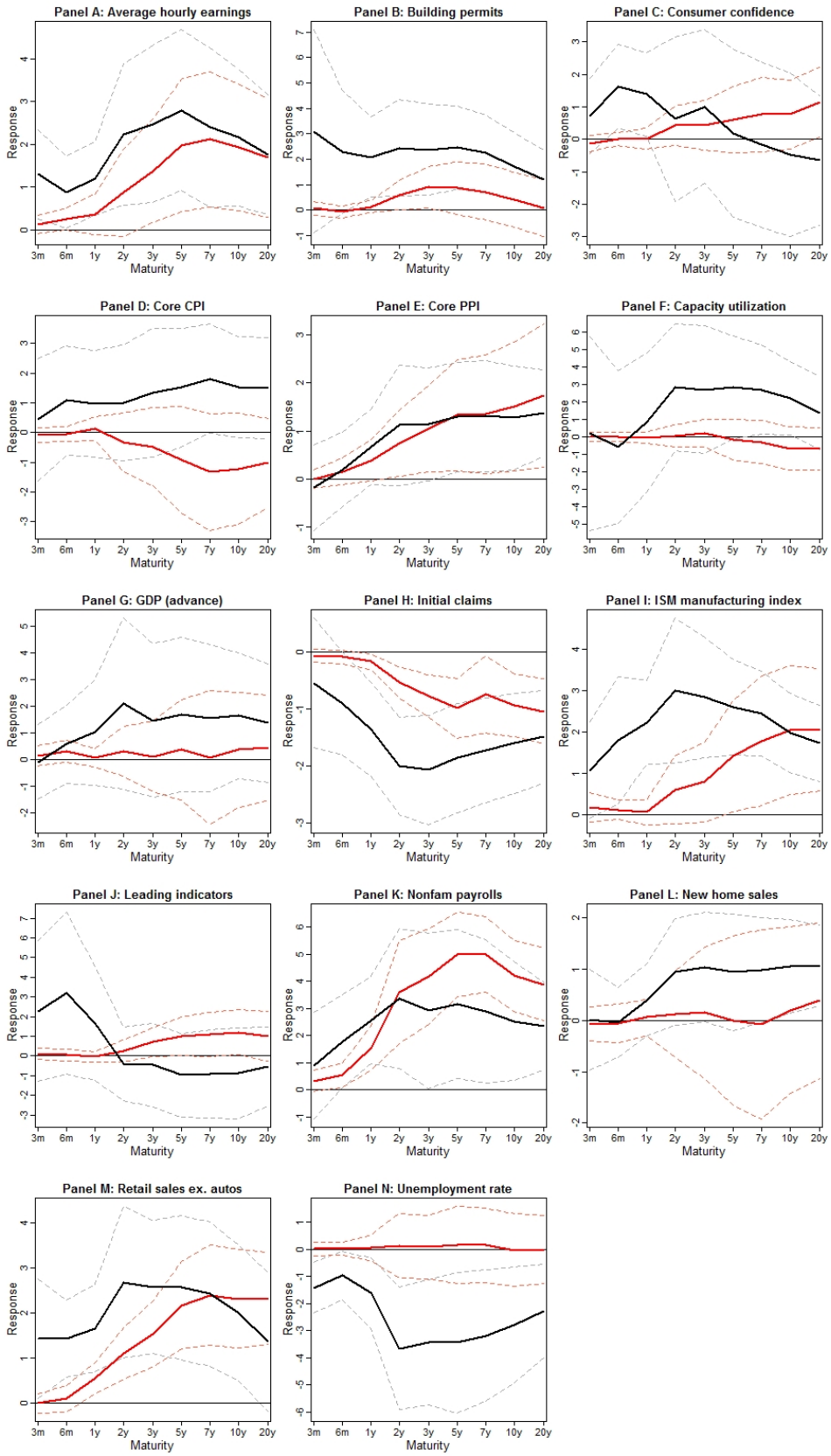
Now we briefly discuss several robustness checks we employed to make sure that our results are not too fragile.

Similarly to Moessner (2014) we attempted to use a dummy variable to specify our regression equation. We added a dummy variable for the ZLB equaling 1 in a low interest rate environment from late 2008 to late 2015, and 0 otherwise, i.e. for the high interest rate environment. To allow for different reactions to news between the periods of the ZLB and of normal times, we also included products of the ZLB dummy with all the normalized surprise components used in Equation 3.1. This approach produced results which were very much alike those presented above. Moreover, we also experimented with adding new data for a short high interest rate period beginning in late 2015 to June 2017 to this dummy variable regression. The results did not change dramatically and thus our conclusions about the effectiveness of Fedâ€™s monetary policy remain the same.

We also ran the regressions using only observations containing at least one nonzero surprise component, i.e. excluding days on which no surprising macroeconomic data were announced. Based on the obtained results, we concluded that the implications of the results presented in Table 5.1 and Table 5.2 remain unchanged.

Moreover, we tried different specifications of the Equation 3.1 by using different sets of explanatory variables. For example, we excluded one or more insignificant variables from the regression, or we removed either nonfarm

Figure 5.2: Estimated effects of the indicators on the yield curve



payrolls, or the unemployment rate, because both of them provide information from the labor market, are published by the Bureau of Labor Statistics, and are typically issued on the same day, at the same time. None of these alternative specifications produced outcomes which would suggest lower validity of the results discussed here.

Lastly, we also attempted to estimate regression Equation 3.1 using rolling regressions in order to capture the time-variation in the sensitivity. We do not provide the results here, because even though we tried several different lengths of the rolling window, the rolling regressions estimated by OLS suffered from small sample issues, as Swanson & Williams (2014a) anticipated. The result was that our coefficients had typically very large standard errors, resulting in large confidence intervals which made inference nearly impossible. On the other hand, the results did not suggest that our analysis here is flawed. Therefore, we do not provide the results for the rolling estimation.

Our results corroborate the findings in Swanson & Williams (2014a) and Moessner (2014). We find the effectiveness of Fed's monetary policy under the zero bound to be lower in terms of the ability to affect shorter-term interest rates, but to the extent that Fed is able to influence longer-term interest rates, we conclude that its monetary policy effectiveness likely remains unaffected by the ZLB.

Chapter 6

Conclusion

In the wake of the 2008 global financial crisis, many central banks decided to cut their monetary policy rates down to essentially zero in order to boost the economy. Thus, the policy rates hit the so-called zero lower bound. There are several reasons to think that the ZLB may reduce the central bank's monetary policy effectiveness. In this thesis, we examine the extent to which the ZLB canstraint might influence the ability of Federal Reserve System to conduct monetary policy.

We began our analysis with the introduction of the theoretical background in Chapter 2. Secondly, we presented the empirical framework of the thesis in Chapter 3. A short description of the data used followed in Chapter 4. In Chapter 5 we presented our results and provided a discussion of their implications.

We find that the sensitivity of the shorter-maturity interest rates to surprising components of macroeconomic news is likely to be attenuated by the presence of the zero lower bound. But with increasing maturity, the yields become less and less constrained, which suggests that the Fed may be able to bypass the ZLB problem and provide stimulus to the economy through the manipulation of longer-term interest rates.

The results support the findings in existing literature that the shorter-term interest rates were constrained by the zero lower bound, but the longer-term interest rates remained unconstrained. The conclusion is that to the extend that the Fed is able to affect those longer-term yields, its monetary policy effectiveness was essentially unaffected by the presence of the zero lower bound.

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