THE EFFECTS OF THE INTEREST RATES ON THE GOVERNMENT BOND LIQUIDITY

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ABSTRACT

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Abstract

Understanding the impact of interest rates on the government bond market is crucial, given that interest rates have traditionally been the primary instrument of monetary policy for central banks. While extensive research has been conducted on the determinants of government bond liquidity, the influence of interest rates during the quantitative easing using Wu-Xia shadow rate remains relatively underexplored. Purpose of this thesis is to study the effects of interest rates on government bond liquidity. To conduct this study, 10-year benchmark government bonds from Finland, Italy and the US will be used. Interest rates will be studied by using Federal Funds Rate, the ECB key rate and Wu-Xia shadow rate to be able to capture the effects of the quantitative easing and the unusually low interest rates. Liquidity is examined by bid – ask spread and the data used are from September 2005 to December 2022. The timeline covers European debt crisis, Covid-19 outbreak, negative interest rates, and various inflation levels.

The results indicate that the changes in the ECB key rate or Wu-Xia euro area shadow rate do not affect the liquidity of Finnish or Italian 10-year government bonds. Shock to the federal funds rate has positive and persistent effect on the US government bond liquidity. On the other hand, results indicate that shock to Wu-Xia US shadow rate has negative and persistent effect on the liquidity of the US government bonds. This is most likely due to Wu-Xia shadow rate's ability to go below zero. Fed decreasing market operations during negative interest rates leads to increase in Wu-Xia shadow rate while reducing the liquidity.

Understanding how changes in interest rates affect government bond liquidity is crucial for policymakers, governments, investors, and financial institutions, as it can provide insights into market dynamics, risk management strategies, and the effectiveness of monetary policy measures.

Key words
Liquidity, government bonds, interest rates, Wu-Xia shadow rate

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1 INTRODUCTION

In this master's thesis, the effects of interest rates on government bond liquidity will be examined. To conduct this study, 10-year benchmark government bonds from Finland, Italy and US will be used. Interest rates will be studied by using Federal Funds Rate, the ECB key rate and Wu-Xia shadow rate to be able to capture the effects of the quantitative easing and the unusually low interest rates. Liquidity is examined by bid – ask spread and the data used are from September 2005 to December 2022. The timeline covers European debt crisis, Covid-19 outbreak, negative interest rates, and various inflation levels. While extensive research has been conducted on the determinants of government bond liquidity, the influence of interest rates during the quantitative easing using Wu-Xia shadow rate remains relatively underexplored. Understanding how changes in interest rates affect government bond liquidity is crucial for policymakers, investors, and financial institutions, as it can provide insights into market dynamics, risk management strategies, and the effectiveness of monetary policy measures. Additionally, exchange organization, regulations and investment management could all be improved with better understanding of factors that influence liquidity.

1.1 Motivation

In recent years, the dynamics of government bond markets have become increasingly important, especially given their role as a benchmark for various financial instruments and their significance in monetary policy transmission mechanisms. Among the various factors influencing government bond markets, interest rates play a pivotal role due to their impact on the cost of borrowing, investment decisions, and overall market liquidity. Inflation numbers reported in Q3 of 2022 have been the highest in the past few decades. Lately, we have experienced dramatic interest rate hikes by European Central Bank and Fed in order to combat high inflation in Europe and in the U.S. Aggressive rate hikes by European Central Bank has led to worries about Italy's debt in the Eurozone. Liquidity is in key role for the investors but as well as for governments when they are trying to fulfil their funding needs. If there is poor liquidity, governments may encounter difficulties when issuing government bonds to fulfil their funding requirements. Liquidity also affects the price of securities. According to Lucas (1990), the price of security will in general depend not only on the properties of the income stream to which it is a claim, but also on the liquidity in the market at the time the security is traded. Liquidity shocks can lead to abrupt and significant declines in bond prices in secondary markets (Lucas, 1990).

1.2 Research questions

Aim of this master's thesis is to find the effects of the interest rates on the government bonds' liquidity and how does the results vary between selected countries. The research questions of this study are the following:

I) How do changes in interest rates effect benchmark government bond liquidity?
II) Do the effects of interest rate changes vary between countries?
III) What other factors causes changes in liquidity?

1.3 Definitions

1.3.1 Liquidity

Liquidity in financial markets can be interpreted as the ability to convert securities into cash, and vice versa at the lowest transaction costs possible (Brunnemeier & Pederson, 2009, Aitken & Comerton-Forde, 2003). According to Brunnemeier & Pedersen (2009) market liquidity has several features:

I) liquidity can suddenly dry up,
II) has similarities across different securities,
III) is correlated with volatility,
IV) is subject to flight to quality,
V) it has correlation with market movements.

Liquidity being subject to flight to quality means that, during the market downturn liquidity differential between high-volatility and low-volatility securities increases, low-volatility securities having better liquidity (Brunnemeier & Pedersen, 2009). According to Goyenko et al. (2011) the liquidity is subject to "flight to liquidity" as well since investors shift towards the more liquid bonds during economic contractions.

When talking about market liquidity, liquidity measures fall into two categories: trade-based measures and order-based measures. Trade-based measures include trading volume, the number of trades and the turnover ratio. The problem with trade-based measures is that they are ex post measures rather than ex ante measures, indicating what people have traded in the past. These measures do poor job indicating the ability of investors to do transactions immediately and the costs associated with that. Order-based measures include order depth and bid-ask spread. The bid-ask spread represents the cost that market participant must incur in order to trade immediately. Based on stock market evidence, order-based liquidity measures provide a better proxy for market liquidity and trade-based measures appear to grossly underestimate and even misrepresent the impact of the crisis on market liquidity. (Aitken & Comerton-Forde, 2003). For this reason, bid-ask spread is used as measurement for liquidity in this study. On top of that, the timeline of this study covers multiple crisis, therefore trade-based measures being unsuitable for this study. Bid-ask spread is market-based measurement, and it can be interpreted as the difference between lowest price that seller is willing to sell asset for and the highest price buyer is willing to pay for that same asset in financial markets. The bid-ask spread can be regarded as the cost that an investor is subject to in order to trade immediately (Aitken & Comerton-Forde, 2003). Smaller spread indicates better liquidity and vice versa. Bid-ask spread is the difference between bid and ask quotes and the spread can be measured in nominal amounts or in percentages/basis points, or bps in short. By calculating spread as a percentage of the asset price, liquidity can be compared across securities with different prices (Aitken & Comerton-Forde, 2003). In this study basis points will be used to measure bid-ask spread. 100 basis points equals to 1%.

1.3.2 Benchmark bonds

According to study by Dunne et al. (2002) benchmark bond can be interpreted as the security with the highest liquidity and in euro-area bonds are issued in euros, or benchmark bond is the security to which the prices of the other bonds react. Study by Boudoukh & Whiteclaw (1991) offers an alternative definition, benchmark bond is the most recent government bond issuance. In most cases, Benchmark status is the combination of them all, since on-the-run bonds are often the most liquid ones of a particular maturity according to study by Warga (1992), and they are the most closely followed. In this thesis, benchmark government bonds are studied in order to find most accurate representation for the market liquidity of 10-year government bonds and the effects of the interest rates have on said liquidity.

1.3.3 Wu-Xia shadow rate

The Federal Reserve has historically used the federal funds rate as the primary tool of monetary policy, lowering the interest rate in order to provide more stimulus and raising the interest rate to cool down economic activity and to control inflation (Wu & Xia, 2016). Federal funds rate has been near zero from December 2008 to November 2015 when the Fed started to raise it. In April 2020 the federal funds rate went back to near zero and remained there until March 2022 due to Covid-19. The effective lower bound of nominal interest rate has been one of the most discussed economic topics of the past decade for good reason, the negative interest rate policy is one of the most recently added tool to unconventional monetary policy toolkit (Wu & Xia, 2020). According to studies by Wu & Xia (2016) and Wu & Zhang (2019) zero lower bound federal funds rate made the Fed to use quantitative easing and forward guidance as tools which were used to affect long-term interest rates and influence the economy. Assessing the impactfulness of the previously mentioned tools or summarizing the overall stance of monetary policy in the new zero lower bound environment was proven to be challenge since the usual methods like Gaussian affine term structure model allows nominal interest rates to go negative, therefore facing difficulties in the zero lower bound environment. (Wu & Xia, 2016). According to Wu & Xia (2016) shadow rate term structure model (SRTSM) offers excellent empirical description of the behaviour of the interest during low interest rate era and important insight to empirical macro literature, where federal funds rate has been used to measure the Fed's monetary policy stance and has given the basis for most empirical studies of the interaction between the economy and monetary policy. According to Wu & Xia (2020) shadow rate is hypothetical short term interest rate if the effective lower bound were not binding and it is interpreted from the term structure of interest rate theory. In this thesis, Wu-Xia euro area and the US shadow rate will be used, which was first proposed in 2016 by the Wu and Xia. Shadow rate equals federal funds rate when the zero lower bound is not binding; when ZLB is binding, shadow rate is negative to account for unconventional monetary policy tools (Wu & Zhang, 2019, Wu & Xia, 2016). Euro area shadow rate is similar to the US shadow rate, but it is developed for euro area.

Wu & Xia (2016) found that shadow rate has similar dynamic relations to important macroeconomic variables before and after the Great Recession and can be used to capture useful information missing from the federal funds rate after the economy reached the zero-lower bound. The timeline of this study covers the zero lower bound environment which is why the shadow rates will also be used in this study.

According to study by Wu & Zhang (2019) there is high negative correlation (-0,94) between shadow rate and Federal Reserve's balance sheet during the quantitative easing. Fed's balance sheet is popular measure for unconventional monetary policy. Market operations are used to purchase assets to Fed's balance sheet which provides additional liquidity. According to study by Wu & Xia (2020) risk premium associated with negative interest rate policy is close to zero or positive, which can be interpreted as agents associating rate cuts with an expansionary monetary policy.

1.4 Structure of the remaining thesis

Remainder of this master's thesis structure is the following: the second chapter is theoretical framework, where deeper look is taken into theories about liquidity and term structure of interest rates. The third chapter will be about the data and methodology used to construct this study. Next, results and analysis of the study and lastly, conclusions about the findings of this study.

2 THEORETICAL FRAMEWORK

In this chapter, theories that explain the effects of the interest rates on government bond liquidity are introduced. Theoretical framework will be mainly focusing on liquidity because of its relevance for conducting this study. In this section I will be going through theories and phenomena that I will be applying when conducting the research. The main theories and phenomena that I will be applying in this master's thesis are flight to liquidity, liquidity preference, liquidity effect and the theory of the term structure of interest rates.

2.1 Flight to liquidity

Flight to liquidity means that investors who are subject to withdrawals and when fund performance falls below a threshold, it generates preference for liquidity (Vayanos, 2004). This theory applies mostly fund managers and during the time of distress when fund managers are trying to get rid of risky or illiquid positions. Flight to liquidity is more prominent during economic distress, we often observe investors rebalance their portfolios towardless risky and more liquid securities, especially in fixed-income markets (Beber et al., 2009, Longstaff, 2004). According to Beber et al. (2009) during market stress, investors are more interested in liquidity compared to credit quality even though credit quality still matter for bond valuation. According to Brunnemeier & Pedersen (2009) there is inverse relationship between fundamental volatility and market liquidity, when market liquidity decreases, fundamental volatility increases. Due to flight to liquidity, illiquid assets become increasingly sensitive to volatility, relative to other assets, as volatility increases. Thus, during volatile times, the negative effect of volatility on the average asset is reflected more strongly on illiquid assets, giving rise to an increased market beta. (Vayanos, 2004). Flight to liquidity phenomenon leads to liquidity premium in bond markets. According to study by Longstaff (2004) flight to liquidity can lead to liquidity premium which can be more than 15% of the value of bonds. This liquidity premium relates to changes in consumer confidence, the amount of government debt available for investors, and flows into equity and money market mutual funds (Longstaff, 2004). According to De Santis (2014) flight to liquidity is behind the pricing of all euro area spreads and, specifically, is the only factor explaining the sovereign spreads for Finland and the Netherlands during the European debt crisis.

Flight to liquidity can lead to economic distress. One example of that is when flight to liquidity occurred in 1998 when Russia defaulted. According to Longstaff (2004), due to Russian default, US Treasury bonds suddenly increased in value relative to less liquid debt instruments, causing credit spreads to widen and resulting to major losses for Long Term Capital Management and many other leveraged hedge funds. Long Term Capital Management collapsed later in 1998 due to heavy losses from Russian default and 1997 Asian financial crisis.

Flight to quality phenomenon is related to flight to liquidity and there may have been elements of both during the 1998 hedge fund crisis (Longstaff, 2004). Flight to liquidity does not only cause economic turbulence, but it can also benefit some countries.

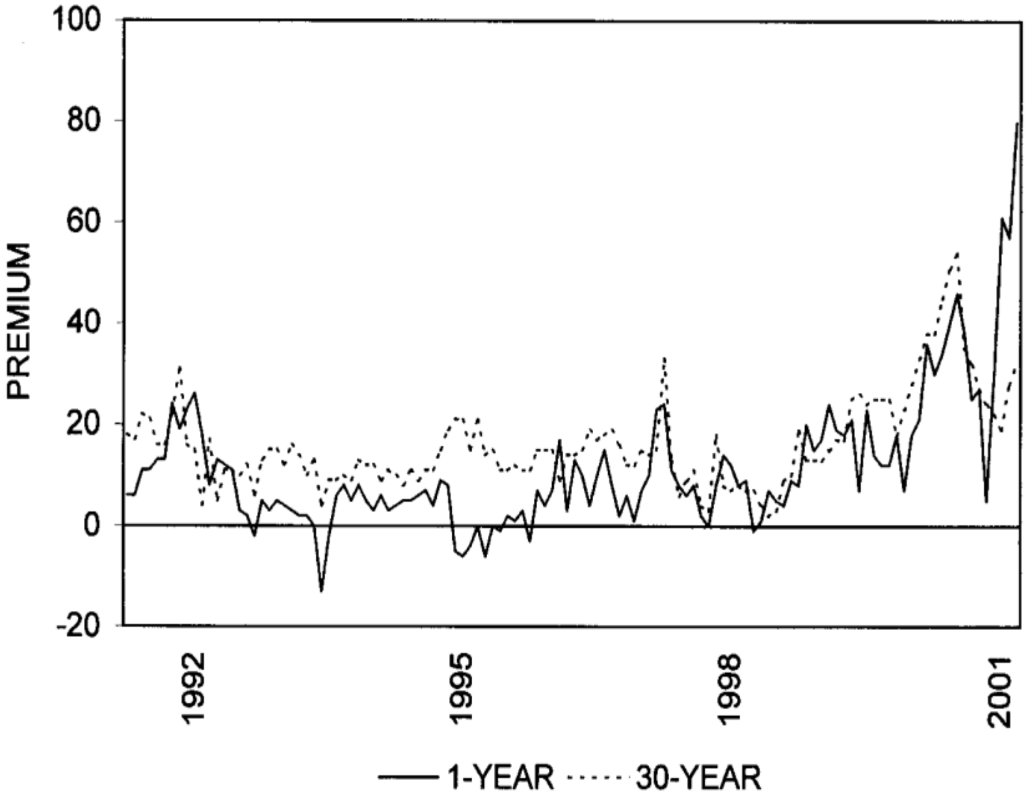

Figure 1. Liquidity premia in the US caused by flight-to-liquidity for 1-year and 30-year maturities from April 1992 to March 2001. Premia measured in basis points. (Longstaff, 2004).

As we can see from figure 1, between 1992 and 1999 there have not been significant growth or decrease in liquidity premia, and it has remained somewhat stable during that time span. There have been few cases when the liquidity premia have been negative. These cases occurred in 1993 and 1995. The first might have been due to end of the early 1990s recession. Negative liquidity premia 1995, might have been result of the Mexican peso crisis since according to study by Whitt (1996) Mexican government suddenly devaluated peso against U.S. dollar in 1994. From 1999 onwards, there is strong increase in liquidity premia lasting to end of this dataset. Main contributor for this is dot-com bubble and the spike in 2001 is due to the terrorist attack that happened in September 2001. Both events led to significant decrease in financial markets and increasing uncertainty. According to flight to liquidity theorem, during economic distress and uncertainty, investors tend to prefer less risky and more liquidity securities, like treasury bonds (Beber et al., 2009, Longstaff, 2004).

2.2 Liquidity preference

In a free capitalistic economy, money services two purposes - as a medium of exchange and form of holding assets. This leads to two sources of demand for money - the transaction demand for money and the demand for money as an asset. This assumption is also the fundamental proposition on which the theory of the rate of interest and money is based on. (Modigliani, 1944). Those two demands for money also gives a good base for liquidity preference theory, where market participants are willing to forgo interest income to hold price-protection assets due to the capital uncertainty associated with relying on market liquidity (Culham, 2020). Liquidity preference theory explains the desire for the macroeconomic or accumulated liquidity available in assets showcasing price protection characteristics, like government bonds (Culham, 2020). According to Modigliani (1944) the transaction demand for money is closely tied to concept of income period and all the assets share two properties – liquidity and risk with varying degrees. Income period can be defined as time between the dates at which members of society are paid for their services.

In order to match the demand for money, there also needs to be supply for money to meet the demand. Based on the results of the study by Modigliani (1994) quantity of active money depends on the total amount of money and on the interest rates and consequently on the form and position of the propensities to save and invest. Active money can be considered as the total quantity of money in circulation. According to Culham (2020) liquidity preference theory states that the interest rate is a monetary phenomenon and not driven by forces of productivity and thrift as some theories suggest. The rate of interest is described as a reward for not hoarding cash or parting with liquidity for a specified period. This description also supports the negative relationship between the rate of interest and liquidity. According to Culham (2020) in liquidity preference theory, market liquidity is referred as liquidity, which is direct consequence of commodity view of money, but this implication also has its drawbacks. Market liquidity as a whole suffers from crisis periods in economy (Culham, 2020). This makes sense since during economic distress market participants try to get rid of their illiquid assets and replace them with highly liquid assets (Vayanos, 2004). In order there to be market liquidity, markets need both buyers and sellers. Problems arise when everyone is trying to get rid of troubled assets which can quickly become very illiquid assets if there are not enough buyers.

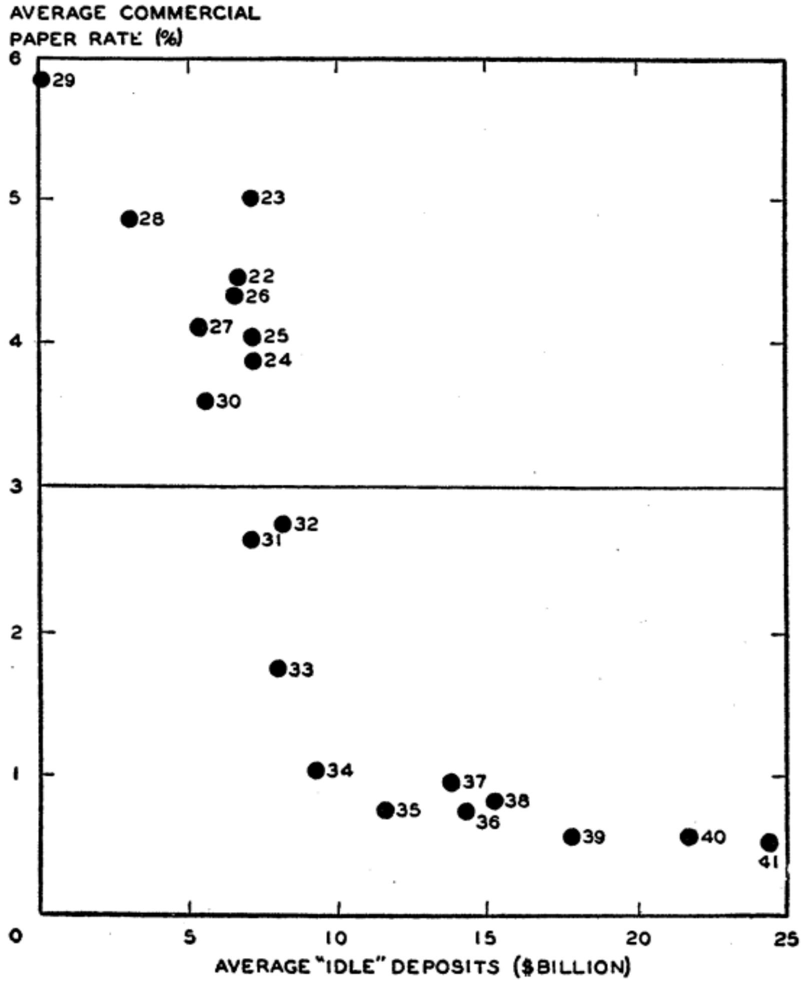

Figure 2. Relationship between average commercial paper rate and average idle deposits in the US from 1922-1941 (Tobin, 1947).

In figure 2, we can see that there is negative correlation between commercial interest rates and idle bank deposits. This might be due to increased quantity of money, which would lead to excess cash balances or due to investors expecting interest rates to increase which would lead to good investing opportunities if this happened. Idle deposits refer to estimation of amount of money that is not required for transactions and is just sitting in deposit accounts (Tobin, 1947). It is noteworthy that in 1929 idle deposits where basically 0 while the commercial paper rate was almost 6%. This might be because the numbers might be from beginning of 1929, when the 1929 Wall Street Crash was still ahead, especially since there was significantly more money in deposits in 1930. This would make sense since preference for liquidity is created by market risk and market liquidity risk (Culham, 2020) and since during economic distress, market risk have often been materialized at that point, people prefer liquid assets, like cash (Vayanos, 2004). The risk aversion of investors will lead to forward rates to be systematically higher than expected spot rates, typically increasing with maturity of bond (Cox et al., 1985). According to Culham (2020) holdings of liquid asset that is in demand by investors, that have speculative motive, depend on how far the current interest rate has fluctuated from the investor's perceived safe level of interest rates. When the current interest rate is below the perceived safe level, there should be strong desire to hold cash until the rate has risen to closer to perceived safe level.

According to Tobin (1947), in liquidity preference theory, increasing the quantity of money creates unwanted cash balances that are then used to acquire securities, driving the prices of securities up and lowering interest rates. The basic functional relationship in liquidity preference theory is an inverse relationship between the demand for money and interest rates (Tobin, 1947). Increased demand increases prices. If the supply does not increase at the same rate, this decrease in interest rates occurs due to the inverse relationship between prices and interest rates. Smaller interest rates lead to increase in spending by encouraging investments or by making saving much less attractive (Tobin, 1947, Culham, 2020). This theory has been seen in full action during the quantitative easing, when central banks, mainly in Europe and US, started to increase quantity of money by doing open market operations in 2010s and early 2020s to boost economies after the financial crisis and European debt crisis. It can be argued that this extended period of quantitative easing contributed to current spike in inflation and increase in interest rates to combat high inflation.

If an asset with capital risk needs to be converted into money, there is no certainty of the valuation of asset at time, therefore cash can be considered as a protection provider against asset-price risk. This uncertainty regarding sales price is not just the transactions cost of illiquidity arising from markets without perfect market liquidity; it is due the uncertainty about future expected returns. (Culham, 2020). This principle can also be applied to at least some government bonds, which tend to have less volatility compared to other easily liquidated assets like stocks. The most liquid government bonds like U.S. treasury bonds can be easily converted into cash even with large quantities within short amount of time which decreases exposure to asset-price risk alongside their lower volatility levels.

2.3 Liquidity effect

Liquidity effect can be described as the negative relationship between money supply and interest rates (Leeper & Gordon, 1992, Cochrane, 1989, Hamilton, 1997, Carpenter & Demiralp, 2006). This can be seen during quantitative easing, when central banks started buying government bonds from secondary markets, providing liquidity to secondary markets, and subsequently decreasing interest rates. The ability of the Federal Reserve to control the federal funds rate relies on the premise of a liquidity effect due to assumption that greater supply of money reserves will cause the federal funds rate to decrease and vice versa assuming *ceteris paribus* (Carpenter & Demiralp, 2006). According to studies by Christiano (1991) and Hamilton (1997), if Federal Reserve wants to decrease the federal fund interest rate, money is injected into the financial markets to push down the federal fund interest rate. The effect of the previously discussed event is thought to be result of two forces: liquidity effect and anticipated inflation effect. In liquidity effect, the additional money pushes down the interest rates, which then provides increase in economic activity. In anticipated inflation effect, sudden increase in money growth makes people to expect more increases in money growth in the future which leads to increased inflation and inflation premium on interest rates by the banks. (Christiano, 1991). Even though previously discussed studies focus on Federal Reserve and the US, the results most likely can be applied to euro-area as well.

According to Christiano (1991) the liquidity effect is the dominating force over the anticipated inflation effect on the short term. Other studies also support this view. According to study by Cochran (1989) the liquidity effect varies between bonds with different maturities, liquidity effect is the most noticeable between 26–52-week window for three-month interest rate and 12–26-week window for the 20-year interest rate. We can interpret from these results that the most noticeable window for 10-year bond rates is most likely also between 12-26 weeks due to their similar characters with 20-year bond. Study by Lucas Jr (1989) found that liquidity effect hast the most significant impact on the one period government bonds. We can interpret from these results that the liquidity effect has the biggest impact on bonds that have shorter maturity, and the effects are short lived. Study by Einarsson & Marquis (2002) provides a possible explanation for the short-lived nature of liquidity effect suggesting that when households are able to adjust their deposits in response to central bank actions, the liquidity effect may disappear.

Study by Christiano (1991) discovered that one percentage point surprise increase in money growth led to greater than two percentage point decrease in the nominal interest rate in the short run. Hamilton (1997) found that unannounced $1 billion decrease in money supply results to 10 basis point increase to federal funds rate and concludes that increased liquidity lowers the interest rate, therefore allowing Federal Reserve to target the federal funds rate on daily basis. Carpenter & Demiralp (2006) found more modest results, the change of billion dollars in reserve balance is adequate to move federal funds rate by almost 3,5 basis points on settlement day. Study by Carpenter & Demiralp (2006) found that the effects of changes in money supply is nonlinear: larger changes in money supply has a measurable effect more consistently than small changes in money supply. Reserve balances and timing also play part on the size of the liquidity effect. Reserve balances at higher aggregate level in banking system is associated with a smaller liquidity effect during the maintenance period, but during the last days of the maintenance period, it leads to larger liquidity effect and the largest liquidity effect occurring on the settlement day (Carpenter & Demiralp, 2006). This might be due to banks needing to fulfill their own reserve requirements by the settlement day therefore leading to more significant liquidity effect.

Explanation behind the liquidity effect according to Cochran (1989) is that when money supply increases, market participants bid up the price of the bonds to earn excess quantity of money, leading to decline of interest rates in short-run and eventually leading to greater inflation. By lowering the interest rates, a lower interest rate encourages companies to borrow more from the banks to scale upwards business operations, creating upward pressure on economic activity (Christiano, 1991).

Previously mentioned studies about liquidity effect do not cover the times of negative interest rates which may or may not have effect on the significance of the liquidity effect. This should be kept in mind due to this thesis covering time periods when negative interest rates where in full effect.

2.4 Term structure of the interest rates

According to Cox et al. (1985) the term structure of interest rates represents the relationship between the yields on default-free securities that are only different in their time to maturity, and it represents the market's anticipations of future events. Study by Shiller & McCulloh (1990) gives similar definition for the term structure of the interest rate: the term of a debt instrument with a fixed maturity is the time until the maturity date and term structure of interest rates at any time is the function relating to interest rate to term. The study of term structure of interest rates studies which market forces are responsible for the changing shapes of term structure or it can also be regarded as the study of market price of time (Shiller & McCulloh, 1990). The term structure of interest rate theory is usually explained with three theorems:

i) expectations hypothesis,
ii) liquidity preference and
iii) market segmentation hypothesis.

Expectations hypothesis suggests that bonds are priced in a way that the implied forward rates to the expected spot rates. Liquidity preference suggests that risk aversion of market participants lead to forward rates to be systematically higher than expected spot rates, gradually increasing with maturity. Market segmentation hypothesis is used to offer one possible explanation for term premiums. Investors have strong preference on different maturities and bonds of different maturities trade in different and distinct markets. (Cox et al., 1985). In this thesis, deeper look is taken into the liquidity preference due to its emphasis on liquidity and pricing of maturities with long maturity.

The term structure is usually upward sloping meaning that long term interest rates are higher than the short-term interest rates and interest rates increases with term. Term structure can get other shapes also. It can be downward sloping or hump shaped, where the intermediate interest rates are higher. (Shiller & McCulloh, 1990). According to Berardi (2009) upward sloping yield curve predicts increase in the level of real activity in economy and flattening or downward sloping yield curve is usually connected with future recession.

3 PREVIOUS LITERATURE

Understanding the dynamics of liquidity and trading activity in financial markets is essential for investors, policymakers, and market participants to make informed decisions and manage risks effectively. A substantial body of literature has explored this topic, revealing the multifaceted nature of liquidity dynamics and its implications for financial markets. This chapter provides a comprehensive overview of key findings from previous studies covering term structure of bond market liquidity, the impact of the macroeconomic variables and monetary policy on liquidity, and the co-movement of liquidity across bond and stock market.

Study by Goyenko et al. (2011) delves into the term structure of bond market liquidity, highlighting the differences in liquidity across bond maturities and between off-the-run bonds and on-the-run bonds. According to Goyenko et al. (2011) during recessions liquidity decreases and the difference between spreads of long- and short-term bonds significantly widens during recessions, suggesting a "flight to liquidity" phenomenon, wherein investors shift towards the more liquid short-term bonds during economic distress. This finding suggests preference for safer assets perceived to offer greater liquidity when market conditions become uncertain. Based on the study by Goyenko et al. (2011) macroeconomic variables such as inflation, federal funds rate, default spread, and term spread emerge as significant predictors of off-the-run bond illiquidity, which is consistent with the notion that these variables affect liquidity through their effects on real wealth and costs of financing dealer inventory and trading activity. However, the predictive power of these variables decreases for on-the-run liquidity, indicating that active trading mitigates their impact on inventory financing costs, being consistent with the notion that active trading in on-the-run bonds mitigates the impact of macro variables on inventory financing costs. Furthermore, shocks to bond returns and volatility affect off-the-run bond illiquidity, emphasizing the intricate interplay between market dynamics and macroeconomic factors. (Goyenko et al., 2011). It can be concluded that the dynamics of on-the-run bond liquidity seem to be driven by somewhat narrow set of economic variables compared to off-the-run bond liquidity.

Goyenko et al. (2011) found that shock to inflation decreases the liquidity of bonds with long maturities, but inflation shocks have no significant impact on medium-bond liquidity. This is in line with the results of the study by Chordia et al. (2005) that positive inflation shocks reduce liquidity by draining trading activity due to it signaling future monetary policy shifts. Shock to federal funds rate forecasts a decrease in government bond liquidity, thus monetary policy tightening appears to decrease bond market liquidity (Goyenko et al., 2011, Chordia et al., 2005) and especially during financial crises monetary expansion, characterized by lower interest rates and increased money supply, increases bond market liquidity and unexpected increases (decreases) in the federal funds rate lead to decreases (increases) in liquidity and increases (decreases) in bond volatility (Chordia et al., 2005). It can be interpreted from the findings of the study by Chordia et al. (2001) that increases in either the short- or long-term interest rate has a significant negative effect on trading activity and liquidity. According to study by Goyenko et al. (2011) bond returns, term spread, and default spread have no significant impact on the on-the-run government bond liquidity, but shocks to volatility have short-lived negative effect on bond market liquidity. In contrast, study by Chordia et al. (2001) found that shock to term spread leads to significantly decreased trading activity, increased bid-ask spreads, and decreased depth. Fleming and Remolona (1997) contribute valuable insights into the role of uncertainty in driving bond market liquidity following announcement surprises. Market uncertainty contributes to heightened trading activity, particularly in response to certain macroeconomic announcements such as employment reports and producer price index (PPI) releases, eliciting more pronounced responses in terms of both price movements and trading activity. It can be noted that the announcements that matter for the price also matters for trading activity, but the degree of the impact can vary. Furthermore, market uncertainty, as measured by implied volatility, contributed to increased trading activity following macroeconomic surprises, further emphasizing the importance of economic data releases in shaping liquidity dynamics. (Fleming & Remolona, 1997). This suggests that uncertainty amplifies the divergence in traders' interpretations of news, leading to increased market activity as participants adjust their positions accordingly. Study by Holden et al. (2014) found that Certain exchange designs enhance market liquidity: a limit order book for high volume markets, a hybrid exchange for low volume markets, and multiple competing exchanges. Automatic execution increases speed but increases spreads. A tick size reduction yields a large improvement in liquidity. Providing ex-post transparency to an otherwise opaque market dramatically improves liquidity. (Holden et al., 2014).

Chordia et al. (2001) provide insights into the co-movement of liquidity across stock and bond markets, emphasizing the interdependence between these markets. Liquidity levels in one market can predict changes in liquidity in the other market, with lagged market returns, interest rates, and spreads serving as significant predictors. During periods of financial crises, stock and bond spreads and volume become more volatile and highly correlated, reflecting increased investor uncertainty and correlated portfolio reallocations. According to Chordia et al. (2001) the bond market spreads lead stock market spreads which is consistent with order imbalances due to portfolio reallocations being reflected first in the institution-dominated bond markets.

In conclusion, shock to interest rates and term spread decreases bond market liquidity and shocks to macroeconomic variables have more significant impact on more illiquid bonds. On the other hand, shock to volatility has significant but short-lived negative impact on bond market liquidity. Market uncertainty leads to increased trading activity, especially in response to macroeconomic announcements. Bond market liquidity correlates with stock market liquidity and bond market liquidity lead stock market liquidity. Based on these findings, I expect interest rates and volatility to affect bid-ask spreads of the selected bonds. Based on the study by Goyenko et al. (2011) it can be expected that inflation, federal funds rate, default spread, and term spread have bigger impact on the liquidity of Italian and Finnish bonds compared to the US bonds, due to macroeconomic variables having more significant impact on more illiquid bonds.

4 DATA AND METHODOLOGY

In this chapter, overview of the data and methodology used in this thesis is provided.

4.1 Data

The data for this thesis has been gathered from the Refinitiv database, FRED and ECB's statistical data warehouse. All the calculations and test statistics have been done by using StataSE 17- program. Data have been gathered using following restrictions:

i) benchmark government bonds from Finland, Italy, and United States of America with 10-year maturities,
ii) monthly data from September 2005 to December 2022 ,
iii) federal funds rate, European Central Bank key rate and Wu-Xia shadow rate for the US and euro area were used as interest rates in estimations,
iv) term spread, volatility of 10-year bond returns and inflation were used as explanatory variables.

Using these restrictions for the data, 84 government bonds in total were used to calculate bid-ask spreads. Timeline of the study consists of 209 monthly observations. For the market data, suitable data starts at September 2005 in Refinitv database and prior to that, there are no quoted bid or ask prices for selected countries on Refinitv database. Similarly to Goyenko et al. (2008) vector autoregression model, Granger causality and impulse response functions are used to estimate if interest rates have effect on liquidity. Set of explanatory variables are used in the estimations alongside of the interest rates. Explanatory variables used in this thesis are: volatility of the 10-year bond returns, country specific inflation and term spread. Term spread is defined as the difference between 10-year yields and 3-month yields and volatility of the 10-year bond returns is estimated as monthly standard deviation of daily returns. Explanatory variables are similar to study done by Goyenko et al. (2008). The reasoning behind the selected countries is the following; Finland is small economy in global scale, but it possess high credit rating. Italy is one of the largest economies in Europe, but its credit rating has not been so good and there were major concerns about the Italy during the European debt crisis. Lastly, the US was selected since its government bonds are the most liquid, it has the largest economy in the world and great credit rating. In short, all selected countries vastly differ in size, two of them are from Europe, but they have very different credit ratings.

The Empirical models are estimated using monthly data from September 2005 to December 2022. In this thesis month end data are used. According to Goyenko et al. (2008) federal funds rate can be used as measurement for the Fed's monetary policy stance. In order to study the effects of the interest rates on the liquidity of government bonds issued by Finland and Italy, European Central Bank key rate was selected to be European equivalent for the federal funds rate. Since the timeline of this study covers the zero lower bound interest rates, Wu-Xia shadow rate was used to gain better understanding of the effects of the interest rates even during unconventional monetary policy and zero lower bound. Bid – ask spread was used as the measurement for liquidity.

Bid – ask spread is market-based liquidity measurement that can be used to measure changes in liquidity. When the spread increases, the liquidity decreases and vice versa. In this thesis, relative quoted spreads are used since according to Goyenko et al. (2008) relative quoted spreads are the standard measure for the treasury market. Basis points are used to measure relative quoted spread. Bid and ask prices are from Refinitiv database for all bonds used in the estimations. Similarly to Goyenko et al. (2008) relative quoted spread is calculated as

$$QS = \frac{Ask - Bid}{\frac{1}{2}(Ask + Bid)},$$

where *Ask* and *Bid* are quoted closing ask and bid prices for the last day of the month. From the spread, basis points are calculated as

$$Bps \ = QS * 10000,$$

where Bps refers to basis points. Smaller spread indicates better liquidity and vice versa.

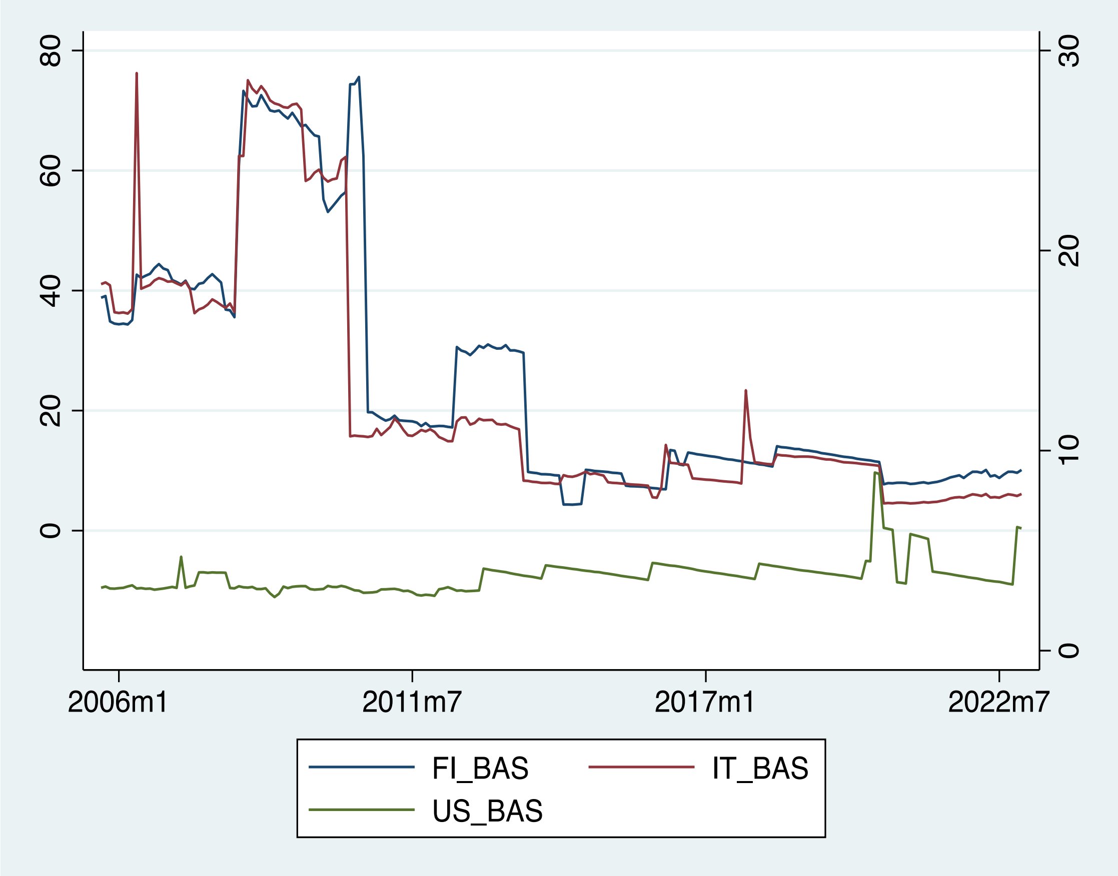

Figure 3. Evolution of bid – ask spread in 10-year Finnish, Italian and the US government bonds between September 2005 and December 2022. Y-axis for the bid - ask spread for the US is on the right hand side of the figure. Spread is measured using basis points, where 100 basis points equal to 1%.

It can be interpreted from figure 3, that US 10-year government bonds are very liquid until the 2020s compared to its peers in this study when measured by bid-ask spread. Italy's are slightly more liquid than Finland's 10-year government bonds. The liquidity of the US government bonds are very stable, but in 2020 there is increase in bid-ask spreads and it reached its highest point at that time, probably due to uncertainty caused by the covid-19. At the same time, Italy reached its lowest bid-ask spread, overtaking the US as having the lowest bid-ask spread. Liquidity also increased at the same time in government bonds issued by Finland, but the increase was smaller compared to Italy. Bid-ask spreads for Finland and Italy seems to be highly correlated even though they have different credit ratings. Both experience big increase in bid-ask spread around 2008 and the spreads remained increased until mid 2010, when the bid-ask spreads quickly decreased. The sudden increase in bid-ask spreads were most likely due to the financial crisis and European debt crisis. The sharp decrease in bid-ask spreads in 2010 is most likely response to the European Financial Stability Facility and European Financial Stabilisation Mechanism, which began operations in 2010.

Finland's liquidity suffers from significant decrease in liquidity in 2012 – 2013. US government bonds' spread fluctuates between 2,68 bps and 8,90 bps, Italy's in between 4,54 bps and 76,23 bps and Finland's in between 4,32 bps and 75,59 bps. As we can see from figure 5, both Italy and Finland have had highest bid-ask spread at some point of this study's timeline and Italy had the lowest for short amount, reflecting country-specific market disruptions and risk.

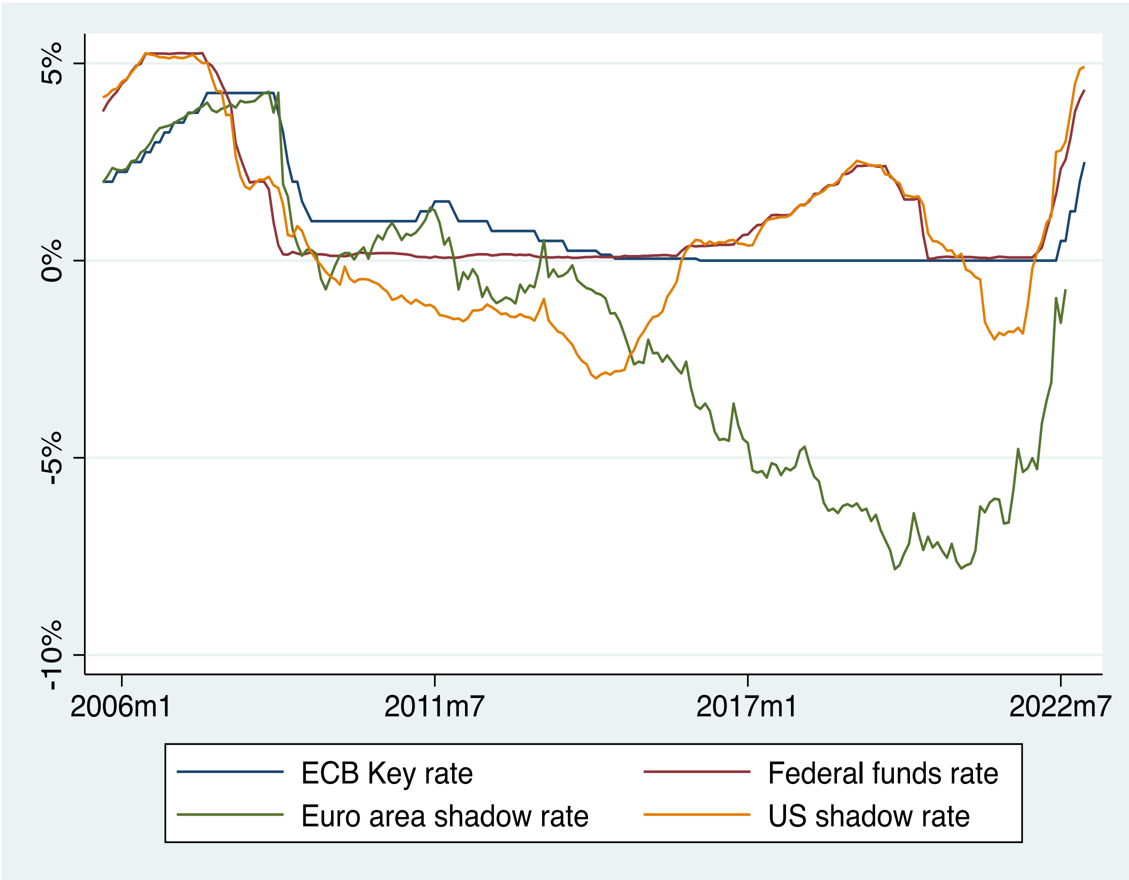

Figure 4. Development of the federal funds rate, ECB key rate and Wu-Xia shadow rate from September 2005 to December 2022. Data for Wu-Xia euro area shadow rate is from September 2005 to August 2022.

In figure 4, it seems like federal funds rate and ECB key rate are correlated, ECB key rate lagging bit behind. This makes sense since euro-area and the US are big markets for each other. Especially US economy plays such a huge part in world economy that when it enters recession, the euro-area will most likely enter recession also. It should not be mistaken that just because the US enters the recession, euro-area will follow for no other reason, it most likely is due to major macroeconomic shock/disruption taking place. This can lead to central banks to change their interest rates to boost economy. The federal funds rate and ECB key rate are major tools in monetary policy toolbox. Due to characteristics of the Wu-Xia shadow rate it closely follows its corresponding interest rate until it reaches zero lower bound as seen in figure 4. Between September 2005 and December 2022, the federal funds rate and ECB key rate both are significant portion of the timeline near zero level, but the Wu-Xia shadow rate can go to below zero. This is the main reason why Wu-Xia shadow rate was included in this thesis. Wu-Xia shadow rate plays pivotal role in this thesis due to its ability to go below zero and explain the effects of the interest rates on liquidity even during quantitative easing. As we can see from figure 4, federal funds rate and Wu-Xia US shadow rate reach their peak at 5,26 % in 2006 - 2007 and ECB key rate at 4,25 % in 2007 – 2008. Wu-Xia US shadow rate reaches its lowest point in 2014 at – 2,99 % which can be considered as extraordinarily low. In 2019 Wu-Xia euro area shadow rate reaches its lowest level of -7,8%. It is worth noting that the Wu-Xia euro area shadow rate was negative for over decade, decreasing below zero at the end of 2011 until the end of the time series. In 2022 the Wu-Xia euro area shadow rate started to increase rapidly marking to end of the quantitative easing.

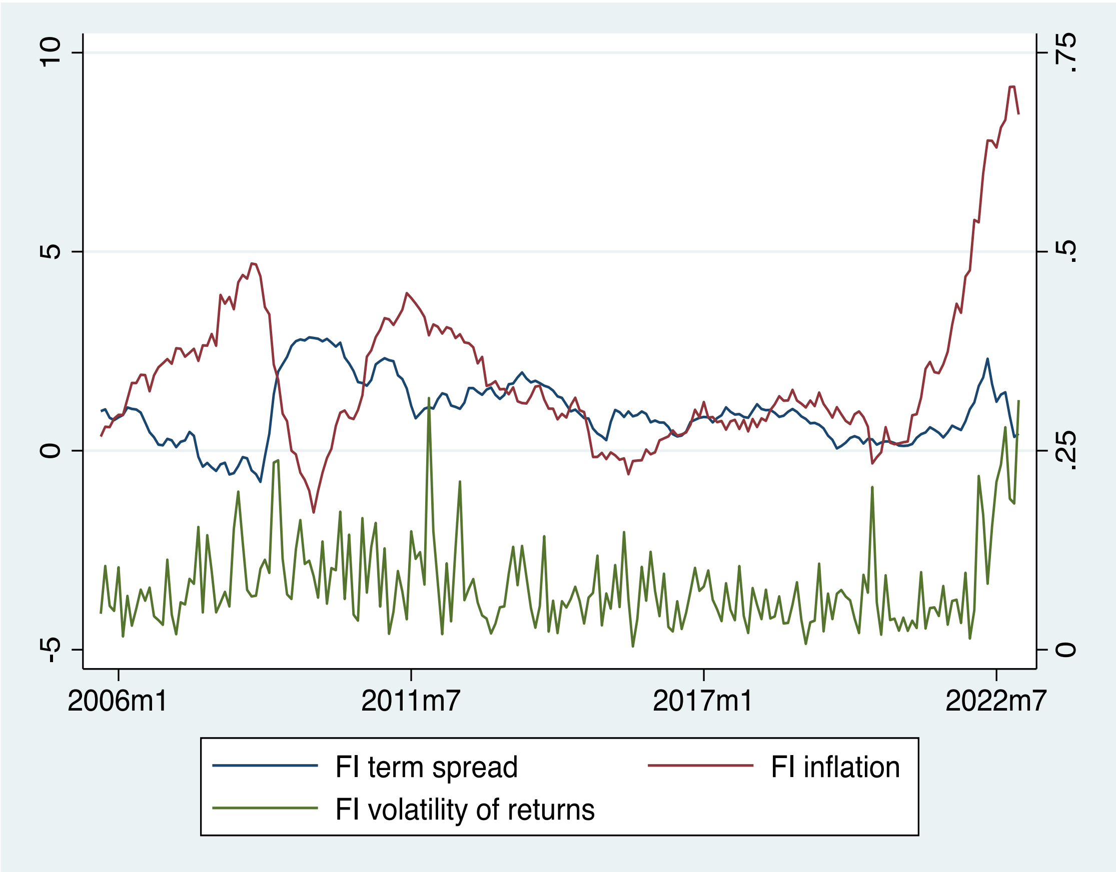

Figure 5. Development of the term spread, inflation and volatility of 10-year government bond returns for Finland during the timeline of September 2005 to December 2022. Y-axis for volatility can be found on the right-hand side of the figure.

It can be interpreted from the figure 5 that the volatility of the 10-year bond yields is low and stable for the most part between September 2005 and December 2022. considering that there have been significant interest rate hikes and decreases by the ECB, credit rating changes, European debt crisis and other events that could potentially have effect on volatility. One explanation might be that Finland have had good credit rating and Finnish government bonds are not as liquid as German or Austrian government bonds that offer similar country risk. Another explanation is that government bonds are considered as low risk investment and during market uncertainty there might be flight to liquidity phenomenon in place. There are two more noticeable volatility increases, the first is during the European debt crisis. The second occurs during 2022 when volatility starts increasing which is probably due to several interest rate hikes and uncertainty towards economy. At the end of 2020, inflation in Finland started slowly to increase and in the second half of the 2021, inflation started to increase fast, and it continued through the remainder of the timeline of the study. From 2007 to 2008, term spread was negative, meaning that short term rates were higher than longer yields. This might have been due to market participants expecting interest rate decreases in the future and as can be seen in figure 4, ECB decreases its key rate during 2009.

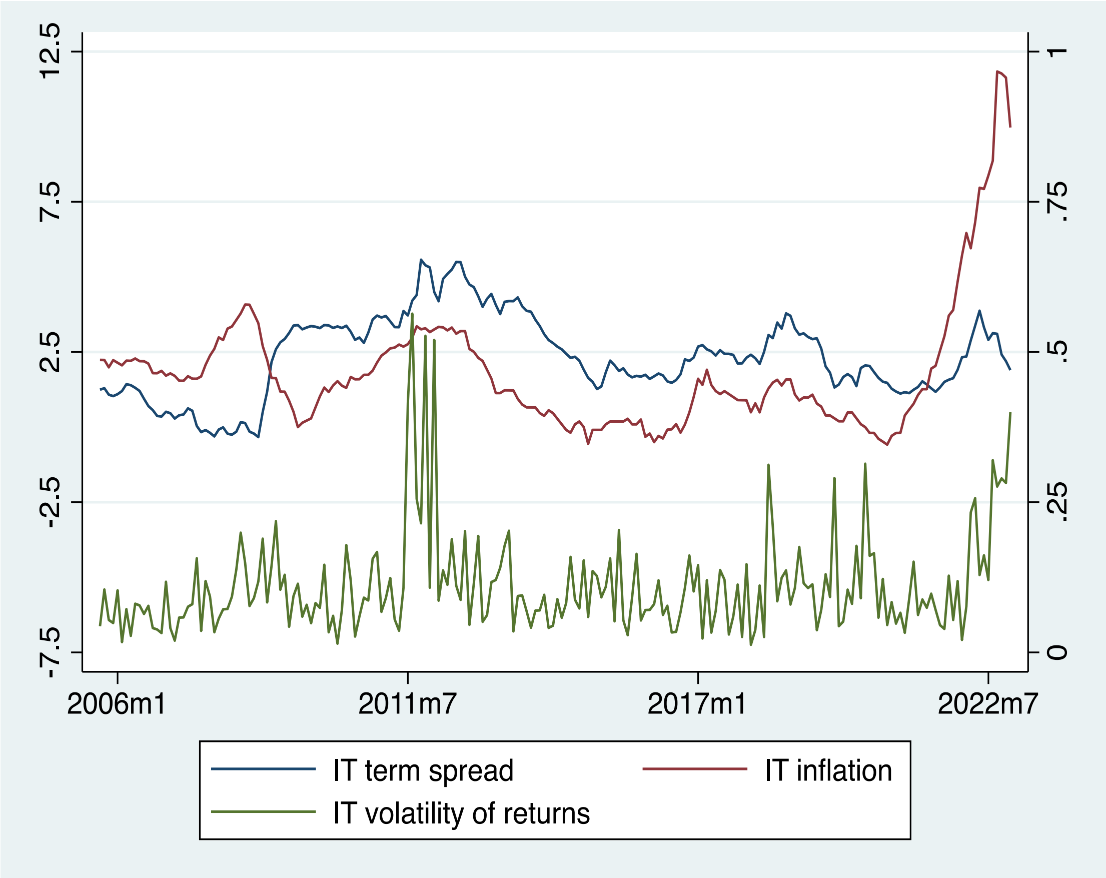

Figure 6. Development of the term spread, inflation and volatility of 10-year government bond returns for Italy during the timeline of September 2005 to December 2022. Y-axis for volatility can be found on the right-hand side of the figure.

Between September 2005 and December 2022, the volatility of the returns is quite low and stable for the most part, but during European debt crisis and in 2022 the volatility increases dramatically, especially during the European debt crisis. Government bonds can be usually considered as low risk investment due to governments ability to collect taxes, which speaks for the low volatility. In figure 6, it seems like there is some level of correlation between inflation and term spread. This makes sense since the inflation in the euro area can cause ECB to increase or decrease its key rate and term spread reflects the views about the development of the future interest rates. It can be interpreted from figure 6 that, when volatility suddenly increases, then the term spread, and inflation also increases. Interestingly, when the inflation or term spread is very low or even negative, it seems like the volatility stays somewhat stable and there seems to be no decrease or increase in volatility in those cases.

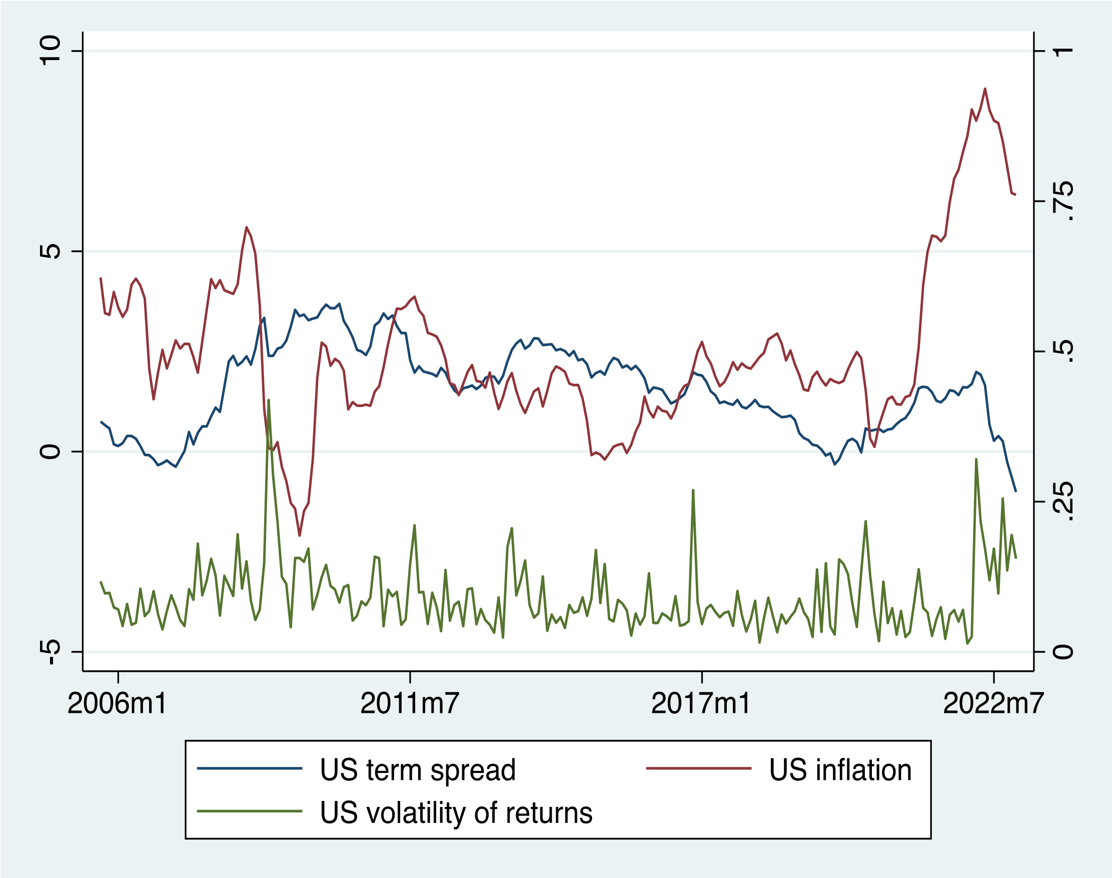

Figure 7. Development of the term spread, inflation and volatility of 10-year government bond returns for the US during the timeline of September 2005 to December 2022. Y-axis for volatility can be found on the right-hand side of the figure.

It can be interpreted from the figure 7 that inflation and term spread are not as correlated as they were in the case of Finland in the figure 5 and Italy in the figure 6 during the timeline of this study. Between September 2005 and December 2022, the volatility of the US 10-year bond returns is again pretty stable, having noticeable increases during the financial crisis, December 2016 to January 2017 and from 2022 onwards. Increase in volatility most likely is due to aggressive federal funds rate increases by the Federal Reserve to combat inflation. Financial crisis caused widespread uncertainty towards financial markets, which can be the cause for increased volatility. On the other hand, in figure 3, the bid-ask spread widens a bit during that time indicating slightly worse liquidity which is surprising since according to flight to liquidity theory during economic distress market participants prefer more liquid securities (Longstaff, 2004).

4.2 Descriptive statistics

To investigate liquidity, this thesis investigates term spread, inflation, volatility of the returns of 10-year government bonds and interest rates. The main focus in this thesis is on the interest rates, but the explanatory variables are also used in the estimations. In this chapter, I will go through descriptive statistics for each country. It is worth noting that both in Italy and Finland, ECB key rate and Wu-Xia euro area shadow rate are used as interest rates and in the US, both the federal funds rate and Wu-Xia US shadow rate are used. In table 1, descriptive statistics are shown for all three countries and for the variables.

Panel A: Data for Italy						
Var/Stat	TERM	INFL	VOLAT	r	esr	IT_BAS
Obs	208	208	208	208	204	208
Mean	2.346	1.792	0.111	0.993	-1.765	21.838
Std. Dev.	1.357	2.105	0.086	1.338	3.635	20.138
Min	-0.333	-0.583	0.013	0	-7.824	4.539
Max	5.572	11.837	0.564	4.25	4.279	76.233
ADF	-10.64***	-10.51***	-9.57***	-8.88***	-14.13***	-18.21***
PP	-10.61***	-10.86***	-10.08***	-9.52***	-14.28***	-18.46***
Panel B: Data for Finland						
Var/Stat	TERM	INFL	VOLAT	r	esr	FI_BAS
Obs	208	208	208	208	204	208
Mean	0.969	1.819	0.081	0.993	-1.765	24.719
Std. Dev.	0.788	1.912	0.055	1.338	3.635	20.284
Min	-0.783	-1.551	0.004	0	-7.824	4.324
Max	2.848	9.145	0.316	4.25	4.279	75.593
ADF	-9.10***	-12.43***	-8.70***	-8.88***	-14.13***	-11.51***
PP	-9.03***	-12.98***	-9.07***	-9.52***	-14.28***	-11.39***
Panel C: Data for US						
Var/Stat	TERM	INFL	VOLAT	r	fedsr	US_BAS
Obs	208	208	208	208	196	208
Mean	1.562	2.465	0.091	1.252	0.539	3.728
Std. Dev.	1.069	2.037	0.057	1.667	2.238	0.845
Min	-1.01	-2.097	0.014	0.05	-2.986	2.68
Max	3.69	9.06	0.419	5.26	5.263	8.903
ADF	-10.83***	-8.57***	-9.52***	-6.32***	-9.40***	-4.49***
PP	-10.79***	-8.44***	-9.60***	-6.15***	-9.76***	-4.57***

Table 1. Descriptive statistics. Table presents the descriptive statistics for the data and variables from Finland, Italy and the US. TERM denotes term spread, INFL denotes the inflation, VOLAT denotes the volatility of the returns of the 10-year government bonds and r denotes federal funds rate in the US and the ECB key rate in the case of Finland and Italy, esr denotes Wu-Xia euro area shadow rate, fedsr denotes Wu-Xia US shadow rate and BAS denotes liquidity measured in bid-ask spread. Significance levels are shown as (***) = 0.01, (**) = 0.05 and (*) = 0.10.

Unit root tests are done by using Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests with the null hypothesis being unit root in the time series. Unit root tests indicate unit root in the time series for the interest rate for all three countries. Unit root tests indicate stationary time series for the term spread, inflation and volatility for Finland, Italy and the US. However, for the liquidity, unit root tests indicate stationary time series only in the US and indicate unit root in the time series for Finland and Italy. Therefore, for the interest rates and liquidity the changes of the variable is used to get stationary time series that are shown in table 1.

It can be interpreted that, the US 10-year government bonds are much more liquid on average compared to 10-year bonds from Finland and Italy. However, it seems like Finland has the least liquid government bonds, but the difference to Italy is only few basis points on average. On the other hand, difference between bonds issued by the US and Finland is roughly 21 basis points. According to Goyenko et al. (2008) term spread widens during economic downturns. Economic downturn can make investors more reluctant to loan especially longer periods, since uncertainty tends to increase during downturns. Italy has the widest term spread of the three, both when measured with the mean value as well as the maximum value. It might be due to Italy's worse credit rating compared to its peers and the European debt crisis had significant impact on government bonds issued by Italy as can be seen in figure 6. Not so surprisingly, on average, Italy has the most volatile 10-year bond yields out of the three. During the European debt crisis, Italy recorded the highest volatility, which is expected since the news about the Italy's economic situation spread widely during that time. Finland has the lowest volatility, which is bit surprising, considering that low liquidity can lead to increased volatility.

Panel A: Correlation matrix for Italy						
Variables	TERM	INFL	VOLAT	r	esr	IT_BAS
TERM	1					
INFL	0.099	1				
VOLAT	0.286***	0.388***	1			
r	-0.483***	0.289***	-0.003	1		
esr	-0.141**	0.326***	0.003	0.843***	1	
IT_BAS	-0.249***	0.03	-0.108	0.714***	0.672***	1
Panel B: Correlation matrix for Finland						
Variables	TERM	INFL	VOLAT	r	esr	FI_BAS
TERM	1					
INFL	-0.118*	1				
VOLAT	0.171**	0.441***	1			
r	-0.316***	0.349***	0.191***	1		
esr	0.100***	0.325***	0.256***	0.843***	1	
FI_BAS	0.205***	-0.001	0.186***	0.681***	0.676***	1
Panel C: Correlation matrix for the US						
Variables	TERM	INFL	VOLAT	r	fedsr	US_BAS
TERM	1					
INFL	-0.267***	1				
VOLAT	0.127***	-0.087	1			
r	-0.697***	0.292***	-0.001	1		
fedsr	-0.699***	0.265***	0.104	0.926***	1	
US_BAS	-0.301***	-0.089	-0.112	-0.105	-0.43	1

Table 2. Correlation coefficients. TERM denotes term spread, INFL denotes the inflation, VOLAT denotes the volatility of the returns of the 10-year government bonds and r denotes federal funds rate in the US and the ECB key rate in the case of Finland and Italy, esr denotes Wu-Xia euro area shadow rate, fedsr denotes Wu-Xia US shadow rate and BAS denotes liquidity. Significance levels are shown as (***) = 0.01, (**) = 0.05 and (*) = 0.10.

It can be interpreted from the table 2, that there is significant level of positive correlation between ECB key rate and liquidity in the case of Italy and Finland, correlation being 0.714 and 0.681 and for Wu-Xia euro area 0.672 and 0.676 respectively. However, in the case of the US, correlation is weak and negative or non-existent, correlation only being -0.43 for Wu-Xia US shadow rate and -0.105 for federal funds rate. It is worth noting that the term spread has the largest correlation with the liquidity of US government bonds, correlation being -0.301, which can be considered fairly low. Also, both the Wu-Xia shadow rate and federal fund rate have surprisingly high negative correlation with the term spread in US, considering that the correlation between ECB key rate and term spread in Italy and Finland is much lower although both having negative correlation. Interest rates seems to have surprisingly low correlation with inflation especially since the interest rates are one of the most important tools central banks use in their efforts to control inflation. The correlation would probably increase if the interest rate variable would be lagged in this correlation analysis.

Panel A: Correlation matrix for interest rates				
Variables	ecbr	fedr	esr	fedsr
ecbr	1			
fedr	0.646***	1		
esr	0.843***	0.413***	1	
fedsr	0.587***	0.926***	0.279***	1
Panel B: Correlation matrix for bid-ask spreads				
Variables	US BAS	FI BAS	IT BAS	
US BAS	1			
FI BAS	-0.437***	1		
IT BAS	-0.411***	0.902***	1	

Table 3. Correlation coefficients for the interest rates and bid-ask spreads. ecbr denotes ECB key rate, fedr denotes federal funds rate, esr denotes Wu-Xia euro area shadow rate, fedsr denotes Wu-Xia US shadow rate, and BAS denotes bid-ask spread. Significance levels are shown as (***) = 0.01, (**) = 0.05 and (*) = 0.10.

As can be seen from table 3 that the liquidity of Italian and Finnish government bond is highly correlated, which is bit surprising considering their vastly different economies and credit ratings. It is noteworthy that euro area and US shadow rate have fairly low correlation (0.279). This is probably due to their differences from mid 2010s to 2020 where US shadow rate rebounded from the below zero and at the same time euro area shadow rate was experiencing its lowest levels. Federal funds rate and Wu-Xia US shadow rate have the highest (0.926) level of correlation among the selected interest rates. The correlation between Wu-Xia euro area shadow rate and ECB key rate is tad lower due to negative interest rates lasting over decade. Another interesting finding from table 3 is that the correlation between the liquidity of Italian and Finnish bonds is very high at 0.902 during the timeline of this study. As can be expected, the correlation between the liquidity of euro area bonds and US bonds is moderate.

4.3 Methodology

The goal of this study is to explore the connection between interest rates and government bond liquidity with the help of selected explanatory variables and empirical models that align with study by Goyenko et al. (2008). In this chapter, deeper look is taken into the empirical models used to construct this thesis.

Vector Autoregressive (VAR) model is a statistical time-series model used to analyze the dynamic relationships among multiple variables over time. Vector

Autoregressive models were popularized by Sims (1980). VAR models extend a univariate autoregressive model to accommodate multivariate time series. Standard VAR model can be given as

$$Y_t = \beta_0 + \sum_{i=1}^{n} \beta_i Y_{t-1} + \sum_{i=0}^{n} \alpha_i X_{t-1} + \varphi D_t + \varepsilon_t$$

where Y_t is vector of endogenous variable while X_t signifies a set of exogenous variables (Stock & Watson, 2020). Previously mentioned estimation is done separately for the bonds issued by the US, Italy, and Finland. In the model, the endogenous variable is bid - ask spread. The exogenous variables are interest rates, term spread, volatility of returns and inflation. Similarly to study by Goyenko et al. (2008) Akaike Information Criteria (AIC) and Schwarz Bayesian Information Criteria were used to determine the optimal lag length for VAR model. VAR model is estimated with one lag in accordance with AIC and Schwarz Bayesian Information Criteria. Goyenko et al. (2008) also did the VAR estimations with one lag.

VAR model enables the forecasting of future variable values based on their relationships with other variables which is one of the reasons why vector autoregressive models are commonly used. When exploring the interdependence of values, it is crucial to verify that the variables are not causally linked. Granger causality test has been popular choice to test for causality among variables. According to Luetkepohl (2011) Granger causality test results can be valuable tool when assessing whether the time series can be used to predict another time series.

In order to estimate time series data, the data needs to be stationary. In this thesis, Augmented Dickey-Fuller (ADF) and Phillips-Perron tests were used to see if the data is stationary. Results from the Augmented Dickey-Fuller and Phillips-Perron tests for each variable can be seen in table in the 3.3 descriptive statistics chapter.

5 RESULTS AND ANALYSIS

In this chapter empirical results will be introduced with corresponding tables and figures. I will be focusing on analysing the liquidity dynamics of government bonds issued by three distinct economies: the United States, Italy, and Finland, aiming to understand how these dynamics react to changes in interest rates. While the broader European bond market exhibits common responses to interest rate fluctuations, each country's unique economic and institutional context may introduce distinctive features to its government bond market. While each of these countries operates within the broader framework of global financial markets, they exhibit unique characteristics and institutional arrangements that influence the behaviour of their respective bond markets. This thesis aims to uncover the intricacies of liquidity dynamics in government bonds and their relationship with interest rates. Additionally, this chapter provides analysis gathered from the empirical models as well as comparison to previous studies.

In Finland, examining the liquidity dynamics of government bonds seeks to enrich our comprehension of the market's resilience and responsiveness to interest rate changes within its specific economic and institutional framework. Similarly, in Italy, where fiscal challenges, structural reforms, and fluctuations in investor confidence are prevalent, analysing the relationship between interest rate changes and bond market liquidity becomes imperative to understand how shifts in monetary policy and macroeconomic conditions reverberate through the Italian government bond market. Moreover, this chapter adds to the broader discussion on bond market liquidity by concentrating specifically on the Italian context, providing valuable insights that can inform investment strategies, risk management practices, and policy formulation within the Italian financial landscape.

Meanwhile, the United States government bond market stands as a cornerstone of the global financial system, representing one of the largest and most liquid bond markets worldwide. Understanding the dynamics of US government bond liquidity and its relationship with interest rates is crucial for investors, policymakers, and scholars alike. By dissecting the relationship between interest rate changes and bond market liquidity, this thesis aims to provide insights into the underlying drivers of liquidity dynamics in US government bonds.

Overall, this analysis of the liquidity dynamics within the Finnish, Italian, and US government bond markets contributes to the broader discourse on fixed-income securities and financial market dynamics, offering valuable insights into how these markets respond to changes in interest rates and macroeconomic conditions.

5.1 Results from Finnish government bonds

First, I will go through the result of the Granger causality test and then moving on to the impulse response functions. All the estimations have been done three times, first with ECB key rate and Wu-Xia euro area shadow rate included, then with only ECB key rate included and lastly only with the Wu-Xia euro area shadow rate. Impulse response function is showed only when both ECB key rate and Wu-Xia euro area shadow rate is included, since the results are the same even when only one of the interest rates is included.

Panel A: ECB key rate and euro area shadow rate included				
Equation	Excluded	chi2	df	Prob > chi2
FI_BAS	VOLAT	0.777	1	0.378
FI_BAS	TERM	0.317	1	0.573
FI_BAS	INFL	0.635	1	0.426
FI_BAS	r	0.036	1	0.85
FI_BAS	esr	0.008	1	0.928
FI_BAS	ALL	1.818	5	0.874
Panel B: ECB key rate included				
Equation	Excluded	chi2	df	Prob > chi2
FI_BAS	VOLAT	0.554	1	0.457
FI_BAS	TERM	0.297	1	0.586
FI_BAS	INFL	0.619	1	0.431
FI_BAS	r	2.7e-05	1	0.996
FI_BAS	ALL	1.567	4	0.815
Panel B: Euro area shadow rate included				
Equation	Excluded	chi2	df	Prob > chi2
FI_BAS	VOLAT	0.765	1	0.382
FI_BAS	TERM	0.298	1	0.585
FI_BAS	INFL	0.738	1	0.39
FI_BAS	esr	0.038	1	0.95
FI_BAS	ALL	1.781	4	0.928

Table 4. Granger causality test for Finland. VOLAT denotes the volatility of the returns of the 10-year government bonds, TERM denotes term spread, INFL denotes the inflation, r denotes the ECB key rate, esr denotes Wu-Xia euro area shadow rate and BAS denotes bid-ask spread.

It can be interpreted from the table 4, that according to Granger causality test, the changes in the ECB key rate or Wu-Xia euro area shadow rate don't explain the changes in the liquidity of government bonds issued by Finland. It is noteworthy that both ECB key rate and Wu-Xia euro area shadow rate get the highest p-values of all the used variables, which contradicts with the findings of studies by Goyenko et al. (2011) and Chordia et al. (2001). Interestingly, it seems like the model used doesn't really explain the changes in the bid-ask spread of the government bonds issued by Finland even when both ECB key rate and Wu-Xia euro area shadow rate is applied. When only ECB key rate is included, inflation seems to do the best in explaining the changes in liquidity. Inflation has the lowest p-level (0.431) of the variables used, but it is still very far from the level required in order to be considered statistically significant. Interestingly when both ECB key rate and Wu-Xia euro are shadow rate is applied (p-value 0.378) or only Wu-Xia euro area shadow rate is applied (p-value 0.382), it's the volatility that is the most useful in predicting the future values of liquidity which is in line with the results of the study by Goyenko et al. (2011). It is good to note that neither of these findings are statistically significant. It was unexpected that the changes in the ECB key rate play such a small part in the changes of the liquidity of the government bonds issued by Finland, since both the ECB key rate and Wu-Xia euro area shadow rate have high correlation with liquidity, correlation being 0.681 and 0.676 respectively.

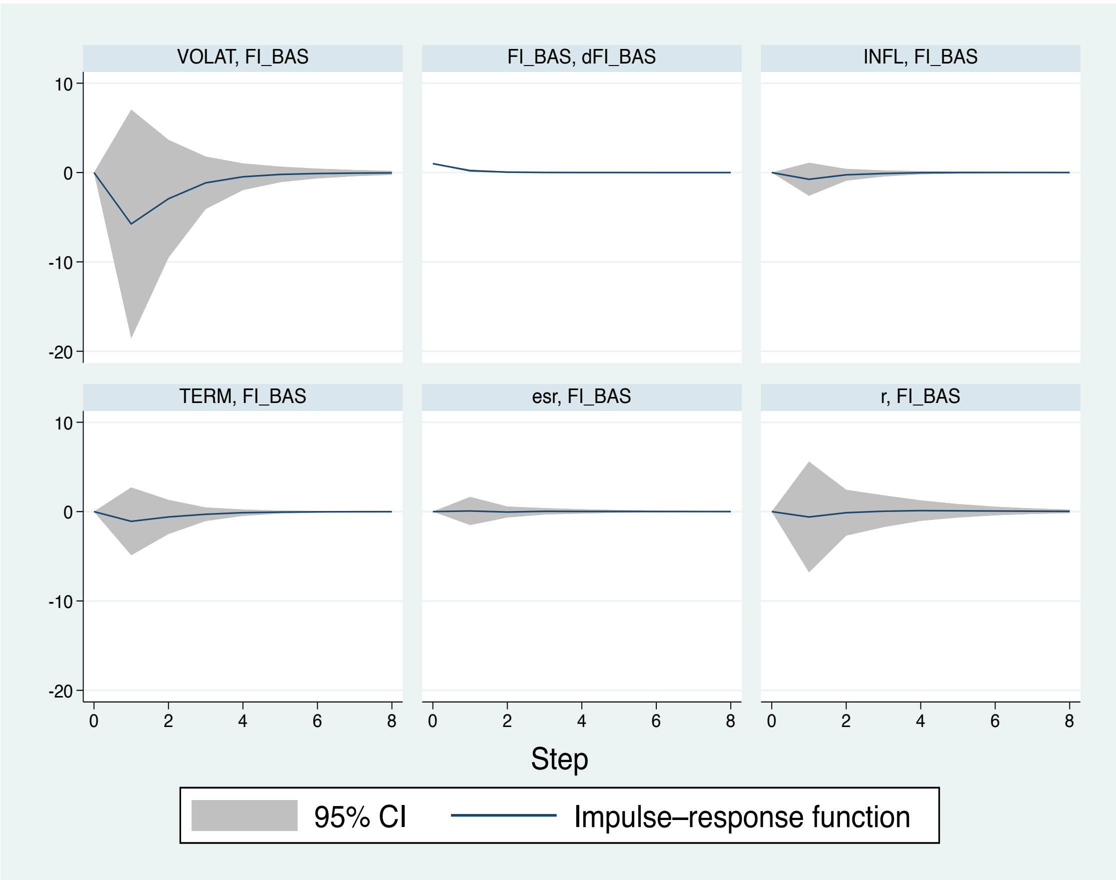

Figure 8. Impulse response functions for VAR model. Figure represents how liquidity of government bonds issued by Finland responds to shocks into different variables. Timeline used is 0 to 8 months.

It can be interpreted from the figure 8 that results from the impulse response function is in line with the granger causality test. Shock to the ECB key rate and

Wu-Xia euro area shadow rate have pretty much zero impact on liquidity of government bonds issued by Finland with flat impulse response function. In the case of ECB key rate, the 95% confidence interval is very wide. Shock to term spread and inflation seem to decrease bid-ask spread marginally, impact being very close to zero. Interestingly, shock to volatility seems to have short-lived impact where it decreases the bid-ask spread by 5 bps. This finding contradicts with the findings of Goyenko et al. (2011), their results suggest that shock to volatility leads to short-lived negative impact on liquidity. After the shock, at one month mark the volatility has the highest impact on liquidity and from there it steadily dilutes back to normal by the month four. It is noteworthy that 95% confidence interval is very wide which is in line with the results from the Granger causality test. It is noteworthy that even shock to liquidity doesn't seem to increase or decrease the liquidity when the response is lagged.

5.2 Results from Italian government bonds

First, I will go through the result of the Granger causality test and then moving on to the impulse response functions. All the estimations have been done three times, first with ECB key rate and Wu-Xia euro area shadow rate included, then with only ECB key rate included and lastly only with the Wu-Xia euro area shadow rate. Impulse response function is showed only when both ECB key rate and Wu-Xia euro area shadow rate is included, since the results are the same even when only one of the interest rates is included.

Panel A: ECB key rate and euro area shadow rate included				
Equation	Excluded	chi2	df	Prob > chi2
IT_BAS	VOLAT	0.168	1	0.897
IT_BAS	TERM	0.067	1	0.796
IT_BAS	INFL	0.818	1	0.366
IT_BAS	r	0.0123	1	0.909
IT_BAS	esr	0.006	1	0.94
IT_BAS	ALL	1.008	1	0.962
Panel B: ECB key rate included				
Equation	Excluded	chi2	df	Prob > chi2
IT_BAS	VOLAT	0.147	1	0.904
IT_BAS	TERM	0.68	1	0.794
IT_BAS	INFL	0.575	1	0.448
IT_BAS	r	0.242	1	0.877
IT_BAS	ALL	0.768	4	0.943
Panel B: Euro area shadow rate included				
Equation	Excluded	chi2	df	Prob > chi2
IT_BAS	VOLAT	0.014	1	0.905
IT_BAS	TERM	0.109	1	0.741
IT_BAS	INFL	0.82	1	0.365
IT_BAS	esr	0.01	1	0.921
IT_BAS	ALL	0.995	4	0.911

Table 5. Granger causality test for Italy. VOLAT denotes the volatility of the returns of the 10-year government bonds, TERM denotes term spread, INFL denotes the inflation, r denotes the ECB key rate, esr denotes Wu-Xia euro area shadow rate and BAS denotes bid-ask spread.

It can be interpreted from the table 5 that, the changes in the ECB key rate and Wu-Xia euro area shadow rate are not useful in forecasting the changes of the liquidity of the government bonds issued by Italy. Inflation seems to be most useful variable from the selected variables in explaining the changes in liquidity. As we can see from table 4, volatility was most useful variable in forecasting the changes in liquidity of Finnish bonds alongside of inflation, but in the case of Italy, the volatility is one of the least useful variables, only behind the interest rates. As we can see from panel A in the table 2, liquidity and ECB key rate had a strong positive correlation (0.714) between those two. Wu-Xia euro area shadow rate and liquidity also had fairly strong correlation of 0.672. Regardless of the high correlation, ECB key rate and Wu-Xia euro area shadow rate are not useful in forecasting the future values of liquidity, which contradicts the findings of Goyenko et al. (2011) and Chordia et al. (2001). Since the timeline of this study covers the quantitative easing therefore central banks being active with their open market operations, providing extra liquidity to markets. This on the other hand can make the liquidity to be less affected by variables such as inflation, interest rates or volatility and be more reliant on open market operations that are conducted by central banks. It can be interpreted from the table 5 that the model used is not very useful in forecasting the future liquidity of the Italian government bonds.

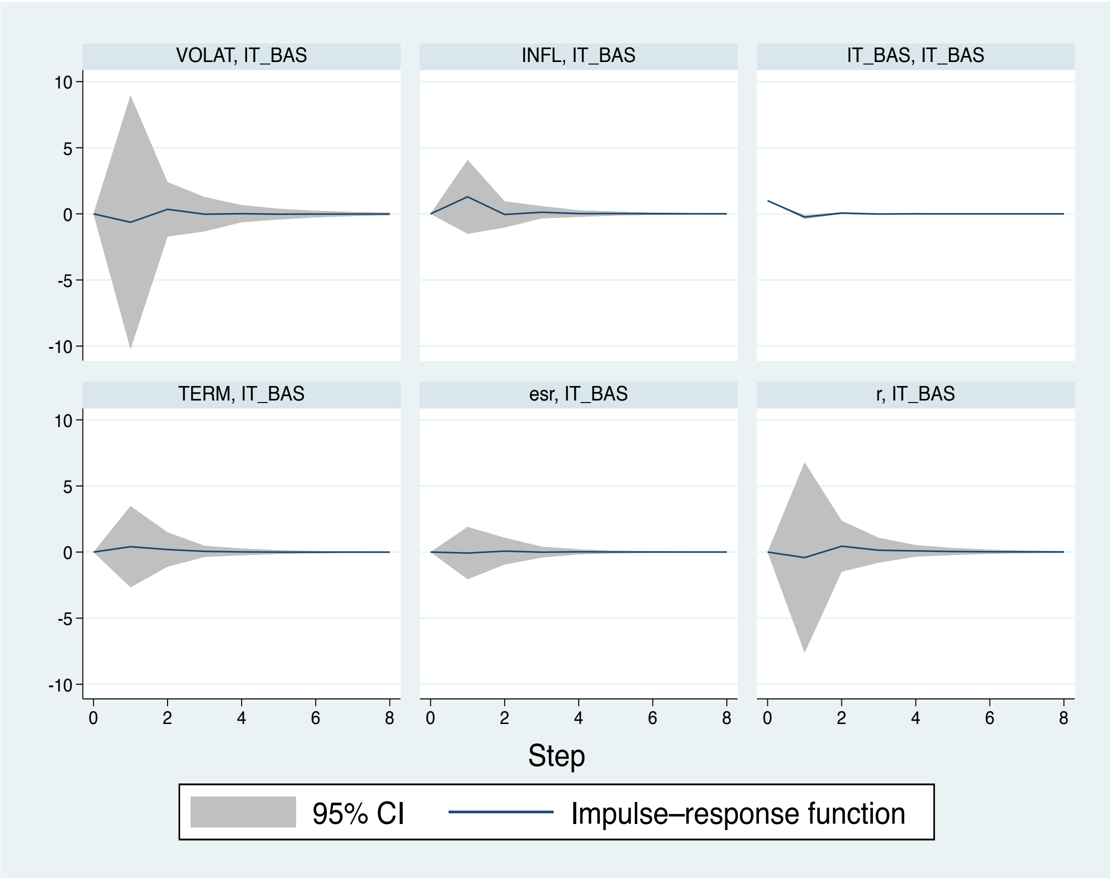

Figure 9. Impulse response functions for VAR model. Figure represents how liquidity of government bonds issued by Italy responds to shocks into different variables. Timeline used is 0 to 8 months.

As can be seen from figure 9, shock to the ECB key rate and Wu-Xia euro area shadow rate have very marginal effect on liquidity of government bonds issued by Italy. This is again in line with the Granger causality test as well as with the results from Finnish data but contradicts the findings from previous literature. Shock to term spread seems to make liquidity marginally worse, which is bit surprising since shock to term spread had the opposite effect on liquidity of government bonds issued by Finland. Shocks to inflation seems to cause different results to liquidity of Italian and Finnish bonds. In the case of Italian bonds, shock to inflation leads to 1 bps increase in bid-ask spreads, whereas shock to inflation leads to marginally smaller bid-ask spreads in Finnish government bonds. Inflation seems to have largest impact on the liquidity of Italian government bonds. Shock to volatility has the opposite effect on liquidity, it marginally increases the liquidity, but again the confidence intervals are very wide, therefore decreasing the reliability. Similar to results from Finland, the biggest effect occurs at the one-month mark and after that it steadily dilutes. As can be seen from table 5, none of the variables had statistically significant ability to forecast the changes in liquidity, which also can be interpreted from the wide 95% confidence intervals. Shock to liquidity seems to have non-existent effect on the liquidity as can be seem in figure 9.

5.3 Results from the US government bonds

This subchapter follows the structure of chapters 5.1 and 5.2. All the estimations have been done three times, first with federal funds rate and Wu-Xia US shadow rate included, then with only federal funds rate included and lastly only with the Wu-Xia US shadow rate. Impulse response function is showed when both federal funds rate and Wu-Xia US shadow rate is included, as well as when only one of them is included.

Panel A: Federal funds rate and US shadow rate included				
Equation	Excluded	chi2	df	Prob > chi2
US_BAS	VOLAT	0.31	1	0.578
US_BAS	TERM	0.191	1	0.662
US_BAS	INFL	0.186	1	0.667
US_BAS	r	15.083	1	0.000
US_BAS	fedsr	0.385	1	0.001
US_BAS	ALL	23.529	5	0.000
Panel B: Federal funds rate included				
Equation	Excluded	chi2	df	Prob > chi2
US_BAS	VOLAT	0.718	1	0.397
US_BAS	TERM	0.072	1	0.788
US_BAS	INFL	1.511	1	0.219
US_BAS	r	4.189	1	0.047
US_BAS	ALL	7.651	4	0.108
Panel B: US shadow rate included				
Equation	Excluded	chi2	df	Prob > chi2
US_BAS	VOLAT	1.244	1	0.265
US_BAS	TERM	1.776	1	0.183
US_BAS	INFL	2.084	1	0.149
US_BAS	fedsr	4.279	1	0.039
US_BAS	ALL	8.094	4	0.088

Table 6. Granger causality test for the US. VOLAT denotes the volatility of the returns of the 10-year government bonds, TERM denotes term spread, INFL denotes the inflation, r denotes the federal funds rate, fedsr denotes the Wu-Xia US shadow rate and BAS denotes liquidity.

It can be interpreted from the table 6 that the federal funds rate and Wu-Xia US shadow rate is statistically significantly useful in forecasting liquidity of government bonds issued by the US. This is somewhat unexpected since the ECB key rate or Wu-Xia euro area shadow rate wasn't useful forecasting the liquidity of government bonds issued by Finland and Italy. Both the federal funds rate and Wu-Xia US shadow rate had relatively small negative correlation with the liquidity, the correlation being -0.105 and -0.43 respectively. According to the results from the Granger causality test, the model is useful in predicting the liquidity when both federal funds rate and Wu-Xia US shadow rate is included. When only one of them is applied, only the Wu-Xia US shadow rate have the p-value less than 0.1 to make it statistically significant. This is mostly due to Federal funds rate and Wu-Xia shadow rate having low p-values, but their very high correlation

(0.925) leads to model seem to have better forecasting power than it really has as can be seen in panel B and panel C.

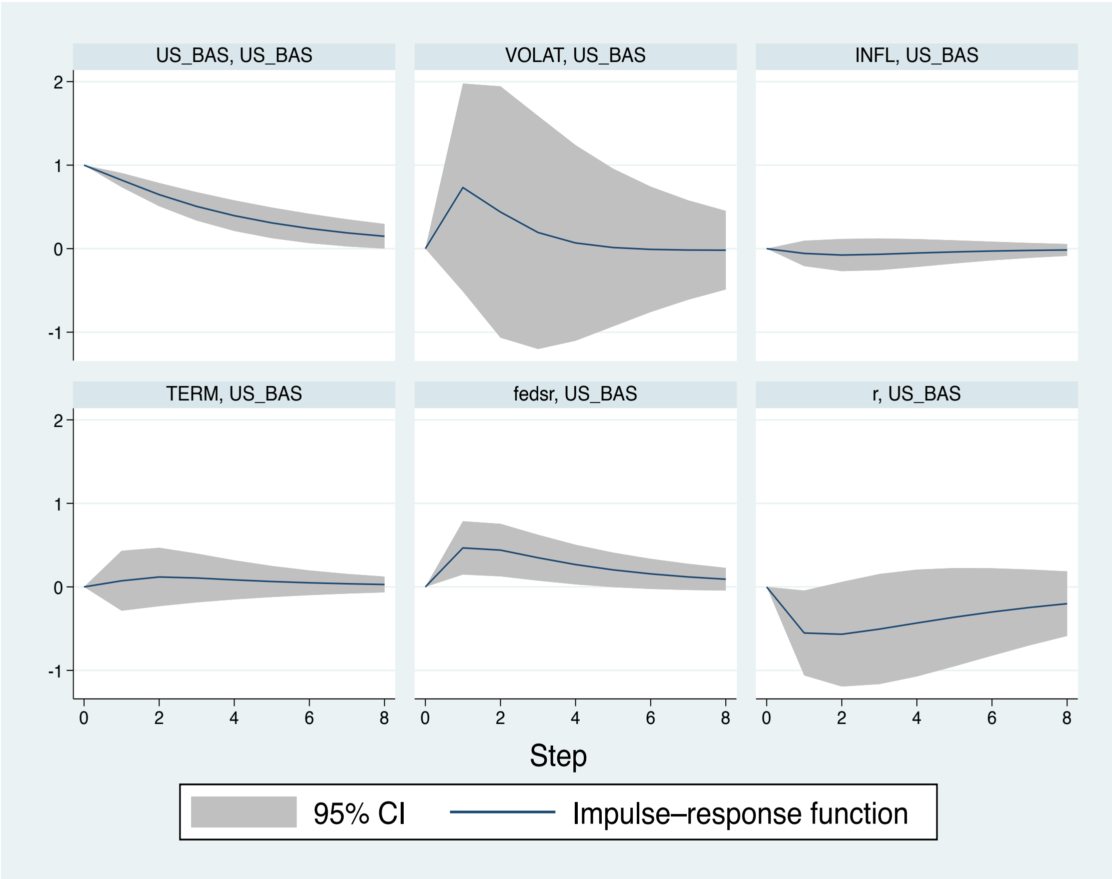

Figure 10. Impulse response functions for VAR model. Figure represents how liquidity of government bonds issued by the US responds to shocks into different variables. Timeline used is 0 to 8 months.

It can be interpreted that shock to the federal funds rate decreases the bid-ask spread of the government bonds issued by the US. This is surprising finding since according to Goyenko et al. (2011) and Chordia et al. (2001) shock to federal funds rate leads to decrease in liquidity. One month after the shock, bid-ask spread would increase by 0.5 bps. The highest increase in liquidity due to shock to the federal funds rate can be seen during the month 2, after that it starts to decrease, but the effects can still be seen at the 6-month mark. It is noteworthy that according to Granger causality test, federal funds rate can be used to forecast liquidity, which differs from the results from Finland and Italy. Surprisingly, shock to Wu-Xia US shadow rate seems to have the opposite effect on the liquidity compared to the federal funds rate. Shock to Wu-Xia US shadow rate increases the bid-ask spread. This finding is consistent with the findings of Goyenko et al. (2011) and Chordia et al. (2001) that shock to interest rates increases bid-ask spread. This is most likely due to zero lower bound and Wu-Xia US shadow rate's ability to go below 0% that was seen during the quantitative easing. During the negative interest rates, when the Wu-Xia US shadow rate increase, it might be due to the FED cutting down the bond purchases, therefore decreasing the liquidity on the markets. Therefore, the effects of the quantitative easing on the government bond liquidity can be seen on the Wu-Xia US shadow rate. The biggest impact can be seen at the one-month mark, where bid-ask spread increases by about 0.5 bps and after that the impact steadily fades away. It is surprising that the shock to Wu-Xia US shadow rate seems to have more short-lived effect on the liquidity of the government bonds issued by the US compared to shock to the federal funds rate. Shock to the volatility seems to produce unique results. At one month mark after the shock to volatility, the bid-ask spread has increased by 0.7 bps, which is in line with the findings of Goyenko et al. (2011). In the case of Finland and Italy, the chart was relatively flat. Shocks to term spread and inflation seems to have close to zero impact on the liquidity. It is good to note that according to Granger causality test, only the Wu-Xia US shadow rate alongside of the federal funds rate had p-values less than 0.10.

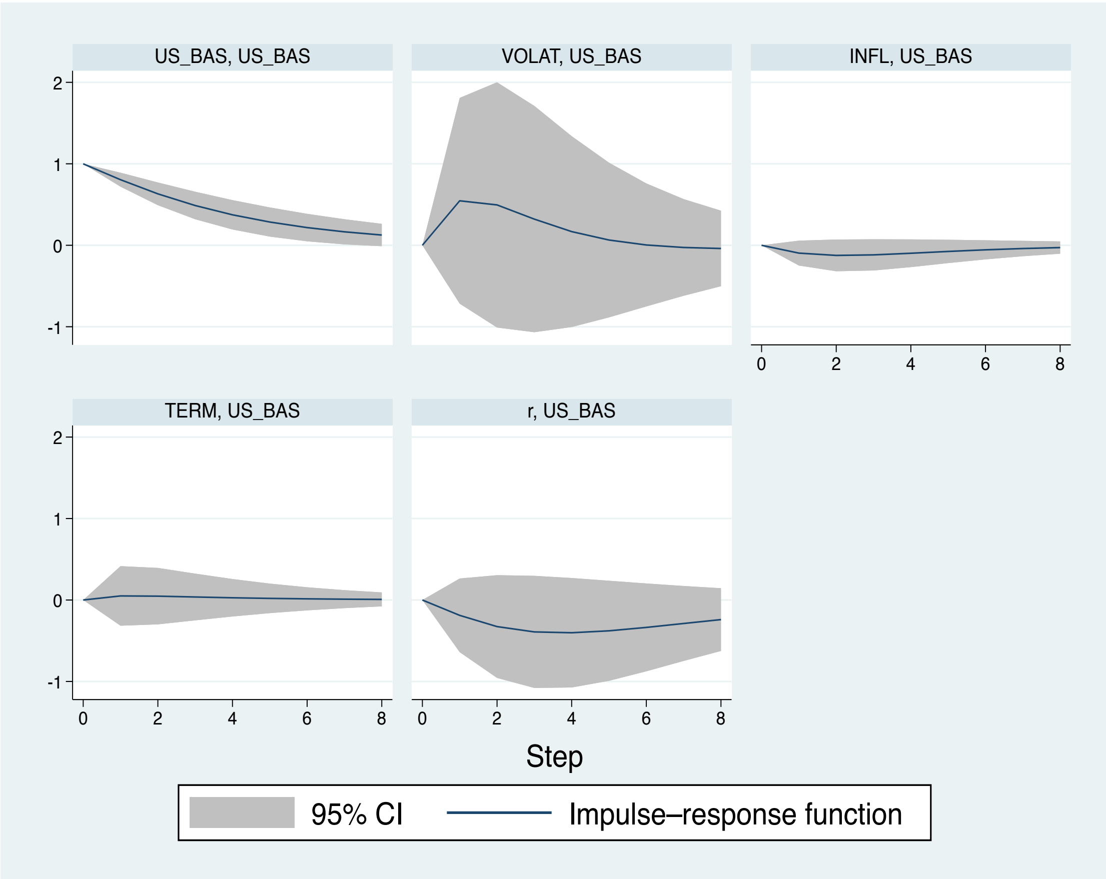

Figure 11. Impulse response functions for VAR model. Figure represents how liquidity of government bonds issued by the US responds to shocks into different variables, Wu-Xia US shadow rate being excluded. Timeline used is 0 to 8 months.

As can be seen from figure 11, when only federal funds rate is applied, shock to federal funds rate has more long-lasting effects compared to when both interest rates are included. Shock to federal funds rate decreases the bid-ask spread by 0.5 bps, the effect being strongest three to four months after the shock. According to Goyenko et al. (2011) shock to volatility has short-lived effect on liquidity, but here the effect seems to last around five months. It is good to note that in Granger causality test, only federal funds rate had the p-value less than 0.10 and that the confidence intervals are very wide for all the shocks except for shock to liquidity. Therefore, drawing conclusions about the impact of shocks is challenging.

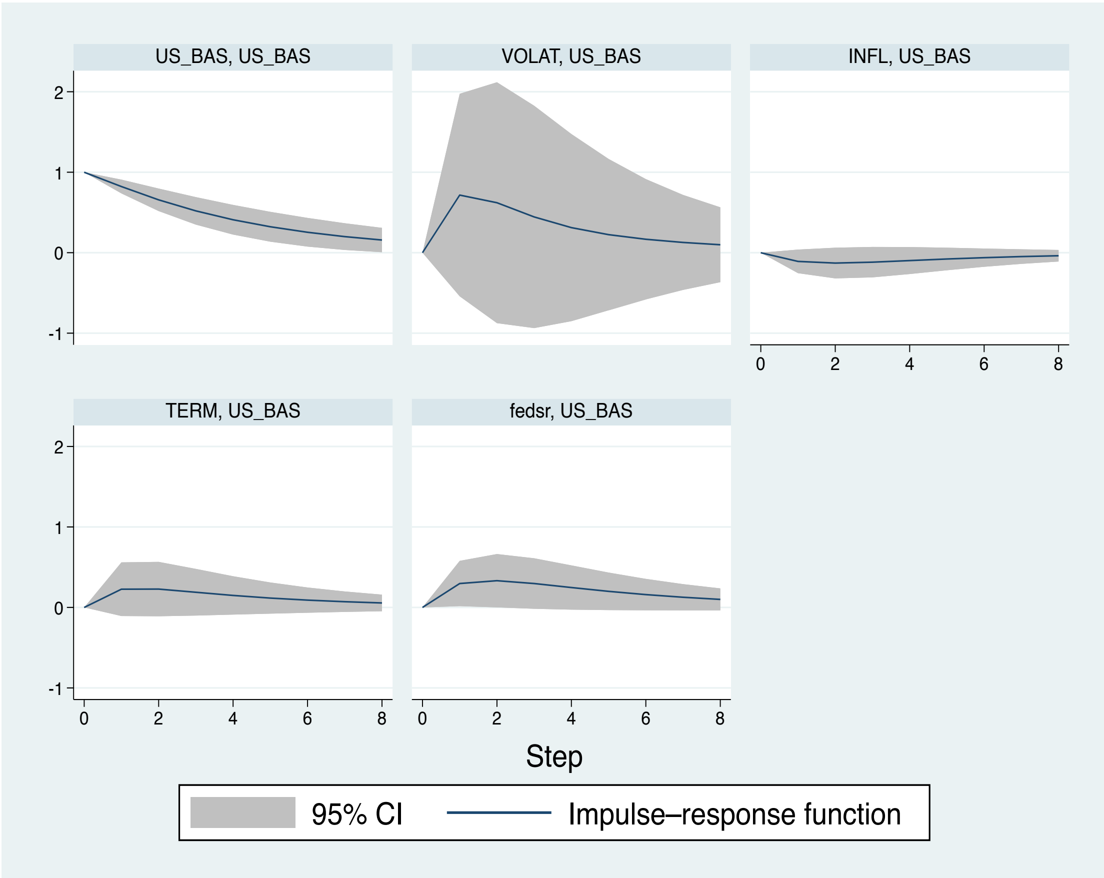

Figure 12. Impulse response functions for VAR model. Figure represents how liquidity of government bonds issued by the US responds to shocks into different variables, federal funds rate being excluded. Timeline used is 0 to 8 months.

As can be seen from figure 12, shock to term spread seems to have marginally larger impact on bid-ask spread when federal funds rate is not included. Interestingly, shock to Wu-Xia shadow rate leads to increased bid-ask spread for eight months. Other than that, rest of the shocks yield similar results as when federal funds rate or both interest rates are involved.

6 CONCLUSIONS

In this master's thesis the emphasis was on the effects of the interest rates on the government bond liquidity. This has been done by using vector autoregression model with the monthly data from September 2005 to December 2022 in Finland, Italy, and the US. This thesis contributes to the current literature by studying the liquidity of government bonds issued by Finland and Italy as well as using the Wu-Xia shadow rate to capture the effects of the quantitative easing on the liquidity.

One of the key findings of the thesis is that positive shock to federal funds rate increases liquidity on the government bonds issued by the US, but shocks to the ECB key rate didn't have impact on the liquidity of the government bonds issued by Finland and Italy. On the other hand, shock to Wu-Xia US shadow rate decreases the liquidity, which is in line with the findings of Goyenko et al. (2011). Wu-Xia euro area shadow rate didn't have much of an impact on liquidity. Studying the whole Eurozone would have led most likely to similar results as the US, since the ECB does not take single country into account, rather focusing on the Eurozone as whole. Interestingly, volatility had the biggest impact on the Finnish bond liquidity and the other variables didn't affect much. Shock to volatility increased liquidity which contradicts the findings by Goyenko et al. (2011). On the other hand, volatility had only marginal impact on the liquidity of Italian bonds, Inflation has the biggest impact on the Italian liquidity even though inflation had only small effect on Finnish liquidity. The findings regarding to the relationship between federal funds rate and liquidity contradicts with the results of the study by Goyenko et al. (2011). Surprisingly, shock to Wu-Xia US shadow rate had the opposite effect on the liquidity than the shock to federal funds rate. It can be interpreted from this finding that the quantitative easing had noticeable impact on government bond liquidity as can be expected. When the Fed cut down the market operations, it led to increase in Wu-Xia US shadow rate and bid-ask spreads getting wider. This adds to existing literature since Wu-Xia shadow rate haven't been used in similar context.

The results suggest that the ECB can't directly affect the liquidity of the government bonds issued by Finland or Italy, but ECB can most likely do so indirectly through the market operations of the respective countries' central banks. On the other hand, the Fed can directly affect the liquidity of the government bonds issued by the US via federal funds rate.

For the further research in this topic, it might be helpful to take into consideration the balance sheets of the central banks. Adding bonds from emerging markets could yield interesting results about the impact of macrovariables. Changes in the credit rating could also be added as a variable to reflect changes in the country risk. It would help us to understand if the changes in country risk drives liquidity.

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APPENDIX 1 Use of AI based tools

In this thesis AI-based tools have been used to improve paragraphs and spelling. To be more precise, OpenAI's ChatGPT was the AI tool used in this thesis.