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QUANTITATIVE EASING EFFECTS ON THE UNITED STATES STOCK MARKET DURING THE COVID-19 OUTBREAK

Bachelor's thesis

Programme Applied Economics

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I hereby declare that I have compiled the thesis independently
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ABSTRACT

This thesis examines the impact of the Federal Reserve's unconventional monetary policy on the United States stock market during the COVID-19 pandemic. The unconventional monetary policy instrument focused on is the large-scale asset purchase, more commonly referred to as quantitative easing. Quantitative easing policies were introduced in the middle of the financial crisis of 2007-2009, and its effects and their specific transmission mechanisms to the real economy and financial markets are not been thoroughly researched yet (Bork 2015; Swanson 2021). This thesis aims to give some insight into the link between quantitative easing and equity prices in the US during the pandemic of 2020-2021.

The proxy used for the quantitative easing is the Federal Reserve's balance sheet, which records the large-scale asset purchases. The asset purchases act as a stimulus for the economy, increasing the money supply and acting as an indicator of economic growth. The analysis is conducted employing a structural VAR model.

The author hypothesises that the quantitative easing measures affected the stock market prices positively or that the effect was not statistically significant. The results partly confirm this hypothesis: the analysis showed a positive but short-term reaction from the stock market in response to the balance sheet shock.

This thesis is divided into three main chapters. The first chapter gives a theoretical explanation of the large-scale asset purchase, the local and global relevance of the US stock market, and previously conducted studies on the subject. The second chapter focused on the data and research methodology used for the empirical analysis. Lastly, the third chapter contains the structural analysis, results, discussion and conclusion.

Keywords: quantitative easing, COVID-19, Federal Reserve System, United States, stock market

INTRODUCTION

Any monetary policy aims to promote stable economic growth by tackling the deceleration in demand and production of goods and services. Consequently, lower demand in the economy leads to a rise in unemployment and a decline in inflation, sparking a drop in overall economic growth. In the United States, this effective operation of nation’s economy is guided by the central bank Federal Reserve System.

Stock market movements have a crucial macroeconomic role in the real economy, and it is imperative to understand the link between monetary policy and financial markets thoroughly. Moreover, in the absence of conventional monetary policy, better insight into transmission mechanisms and the severity of the relationship between unconventional monetary policy and the equity market is vital for preserving economic stability (Swanson 2021).

This bachelor’s thesis focuses on the effects of unconventional monetary policy measures on the United States stock market during the COVID-19 outbreak. In particular, the unconventional policy instruments analysed in this thesis are the large-scale asset purchases, more commonly referred to as quantitative easing policies. This bachelor’s thesis aims to investigate how the Federal Reserve’s actions have impacted the shares of the five hundred largest US public companies’ market capitalisations from March 2020 to December 2021. The author hypothesises that the quantitative easing measures affected the stock market prices positively or that the effect was not statistically significant.

Many central banks globally have adopted unconventional monetary policy measures, such as large-scale asset purchases, in the last decades, despite the policy effects not being fully understood (Bork 2015; Swanson 2021). Therefore, examining the unconventional monetary policy impacts on the real economy is imperative. There are only a limited number of studies on the effects of quantitative easing of 2020-2021 on the US stock market, and this thesis aims to fill that gap.

The primary analysis is conducted using a structural vector autoregressive time series model. The analysed data is accessible from the Federal Reserve of St. Louis (FRED) economics database. The structural VAR model allows to examine time series variables' interactions through their lagged values, providing an efficient macroeconomic and policy analysis method. It has been used extensively for similar works. (Stock, Watson 2001) The constructed SVAR model contains six variables with four lags.

In this thesis, the proxy used for the quantitative easing is the Federal Reserve's balance sheet. The stock market is represented by the Standard and Poors' 500 stock market index. Other explanatory variables are the federal funds effective rate, the 2-year Treasury bond yield, the 15-year mortgage rate index, and the United States' gasoline price.

The thesis is composed of three chapters. The first chapter gives a theoretical explanation of quantitative easing policies and the relevance of the United States stock market. In addition, the chapter inspects the theoretical and previously found associations between the increase in Federal Reserve's assets and the stock market. In the second chapter, the author gives an overview of the data and explains the research methodology. Finally, the third chapter contains the model analysis results, interpretation, macroeconomic discussion, and conclusions.

The author would like to take this instance to thank her supervisor Signe Rosenberg for the provided inspiration and assistance that allowed this thesis to be completed.

1. UNCONVENTIONAL MONETARY POLICY EFFECTS IN THE US

In this chapter, the author discusses the essence of large-scale asset purchases, the local and global relevance of the US stock market, and the presumed effects of unconventional monetary policy on financial markets. This chapter entails previous empirical studies and their results on unconventional monetary policy and its effects.

1.1. Large-scale asset purchases

In the United States, the board responsible for adjusting monetary policy to secure maximum employment, stabilise prices and long-term interest rates is the Federal Open Market Committee (hereinafter FOMC) (Federal Reserve ... 2021). The conventional instrument used to conduct monetary policy is adjusting the target for the federal funds rate (Bernanke, Kuttner 2005). This represents the rate at which depository institutions in the United States charge each other to lend or borrow excess reserves overnight (Federal Reserve ... 2021). In other words, the federal funds rate determines the cost of credit for the banks and the public, therefore providing an efficient tool to influence the real economy.

The Federal Reserve states that the rate has been a dependable policy instrument, with research confirming that it directly impacts long-term interest rates, returns on the US Treasury bonds, credit rates, and mortgage rates. Moreover, the rate has affected asset prices and exchange rates and is seen as the measure of future expectations for economic growth. (*Ibid.*)

Since the last recession in 2007-2009, the federal funds rate has roughly been at near-zero levels (see Figure 1). Since physical currency holds a zero nominal return, it is impossible to lower the rate below zero. Therefore, unconventional policy measures are limited in zero lower bound (hereinafter ZLB) conditions. (Swanson 2021) However, the start of the ZLB period amid a recession meant an imminent need for effective unconventional monetary policy instruments.

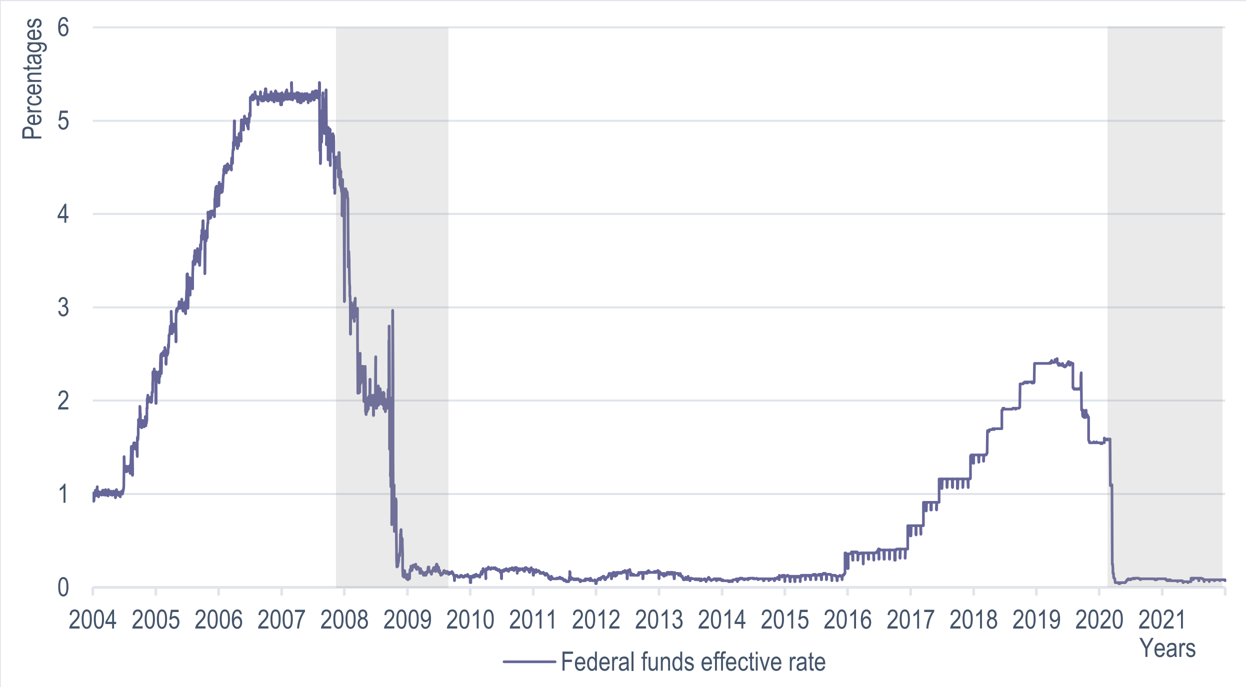

Figure 1. Federal funds effective rate 2004-2021
Source: Merila (2022a); figure created by the author in Excel

From the start of the ZLB period, FOMC began employing unconventional tactics to boost the economy (Gertler, Karadi 2018; Swanson 2021). The implemented measures were large-scale asset purchases and the related forward guidance. The latter is another unconventional monetary policy tool used to guide households' and businesses' expectations toward better future market conditions (Eksi, Tas 2017). However, in this bachelor's thesis, the effects of forward guidance are not discussed.

The unconventional monetary policy tool in focus is the large-scale asset purchase (hereinafter LSAP). LSAPs are security purchases made by the Federal Reserve Board to stimulate the economy by spurring up the demand for goods and services. LSAPs are also known as quantitative easing policies (Mamaysky 2018), where the Federal Reserve invests hundreds of billions of dollars in US Treasury bonds and mortgage-backed securities (Bork 2015; Swanson 2021). Essentially, quantitative easing increases the money supply, and the most common conception of quantitative easing projects is that they reflect fast money creation (Gertler, Karadi 2018; Al-Jassar, Moosa 2019). The predicted effect of LSAPs on the economy is similar to the conventional monetary measures, resulting in improved credit conditions (Swanson 2021) and improvement in the real economy (Bork 2015).

Fed reports that over the six years since the beginning of the ZLB period, purchases of approximately 3.7 trillion dollars were made in longer-term Treasury securities and securities issued by government-sponsored enterprises. The objective of the Fed was to increase the balance sheet in times of recession and start selling the securities after reaching economic stability. (Federal Reserve ... 2021) Figure 2 reflects the rapid increase in the balance sheet from the end of 2008 and the steady incline up to 2014.

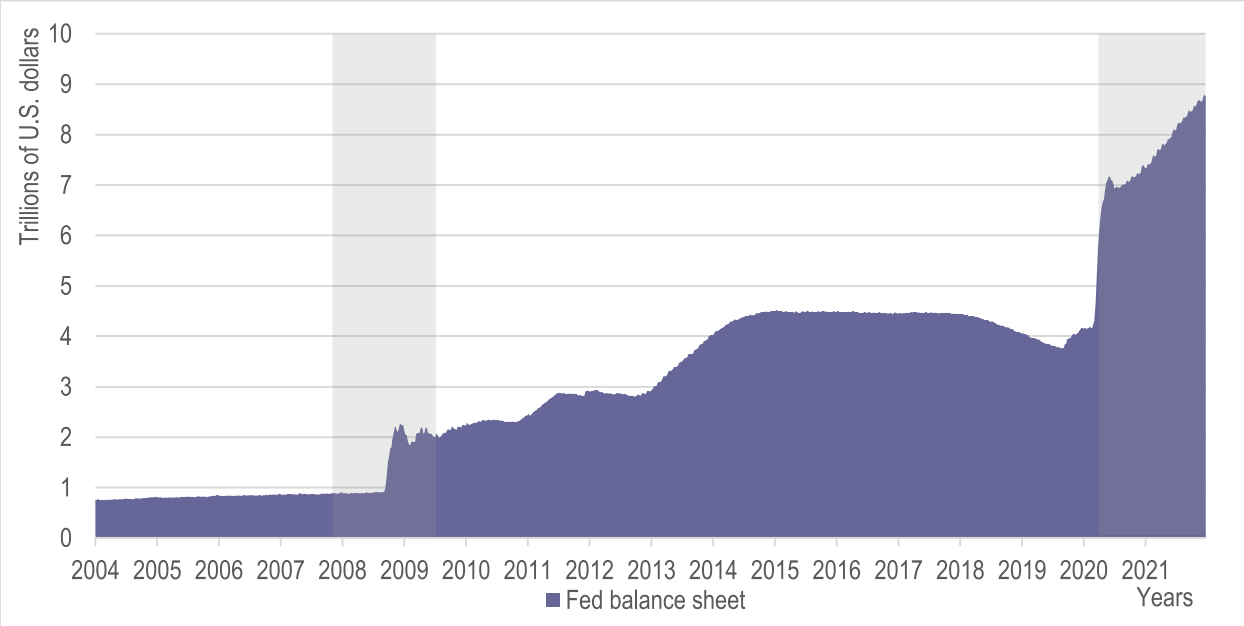

Figure 2. Federal Reserve’s assets 2004-2021
Source: Merila (2022b); figure created by the author in Excel

In December 2015, FOMC initiated a gradual return to conventional monetary policy, gradually increasing the federal funds rate target (see Figure 1). As seen in Figure 2, as of October of 2017, Fed also began selling previously purchased securities. By July 2019, the effective rate reached 2.4 per cent (see Figure 1), and monetary policy was shifting towards normalisation. (*Ibid.*) However, as the COVID-19 outbreak started to affect the global and local economy in early 2020, the federal rate target quickly dropped to near-zero levels again (see Figure 1).

As Fed states on its homepage, the virus and concurrent political measures induced a sharp decline in economic activity and an upswing in unemployment, which „had been at a 50-year low, soaring to a postwar record high”. After the federal funds rate target reduction, there was still an immense need for additional measures to promote the smooth functioning of financial markets and supply the stream of credit to households and businesses (The Fed ... 2020). Therefore, the FOMC immediately announced another asset purchase program (Allen 2021).

Starting from March of 2020, FOMC purchased Treasury securities, residential and commercial mortgage-backed securities, expanded repurchase agreement operations, and augmented additional credit and liquidity facilities. These activities resulted in massive growth in the Federal Reserve's balance sheet (see Figure 2). As a result, the balance sheet grew from 4.2 trillion dollars at the start of 2020 to 7.2 trillion dollars in June. Respectively, the balance sheet increased from representing 19 per cent of US nominal gross domestic product to 33 per cent (*Ibid.*), nearly doubling in six months.

There are some controversial opinions on the efficiency and potential outcomes of LSAPs, when considering the financial markets. Quantitative easing is estimated to support the economy in the long run by stopping panicked behaviour among investors. (Zhang *et al.* 2020) However, according to Gromsen and Koijen (2020), the policies can create inconsistencies in investors' long-term expectations.

1.2. The United States stock market

There is considerable evidence to link the stock market's performance to economic growth (Gurley, Shaw 1955; Marty 1961; Bahadur, Neupane 2006; Masoud 2013). The stock market efficacy is essential for wealth accumulation and corporate financing and, therefore, a determinant factor in production, demand and consumption. Furthermore, the stock market plays a vital role in mobilising savings, diversifying risks, resource allocation and trade. (Bahadur, Neupane 2006) Thus, the financial market is also correlated with employment (Farmer 2012).

There is some debate on transmission mechanisms through which the stock market affects the real economy. According to Bahadur and Neupane (2006), the stock market development is assumed to have a developmental role in global economics. Additionally, there are several other theories: the „wealth effect", which claims that the stock market movements explain the variation in the real economy, and the fundamental values model, which states that the stock prices reflect the market's future expectations. Both of these theories provide a theoretical argument that stock prices act as an indicator of economic development. (Comincioli 1996; Bahadur, Neupane 2006)

The COVID-19 (commonly referred to as the coronavirus) outbreak was declared a global emergency by the World Health Organization in March of 2020 (Yousfi *et al.* 2021). The United

States was severely affected by this virus as it significantly impacted the country's economy (Zhang *et al.* 2020). Although there have been several infectious disease outbreaks over the past decades, there have not been any remarkable impacts on the stock markets (Baek, Lee 2021).

In the 2007-2009 financial crisis, the NASDAQ Composite Index, representing more than 3000 companies in the US stock market, fell by 1350 basis points (see Figure 3). At the same time, the Volatility Index by the Chicago Board Options Exchange (hereinafter VIX), which calculates the current volatility in the stock market, rose by as much as 60 index points over a few months (see Figure 3). Both variables stabilised by the end of the crisis. However, in March 2020, the NASDAQ Composite Index fell by over 2950 basis points, and VIX increased by as much as 65 index points over only one month. From the initial outbreak until the end of 2021, the stock index increased by about 8000 basis points (see Figure 3).

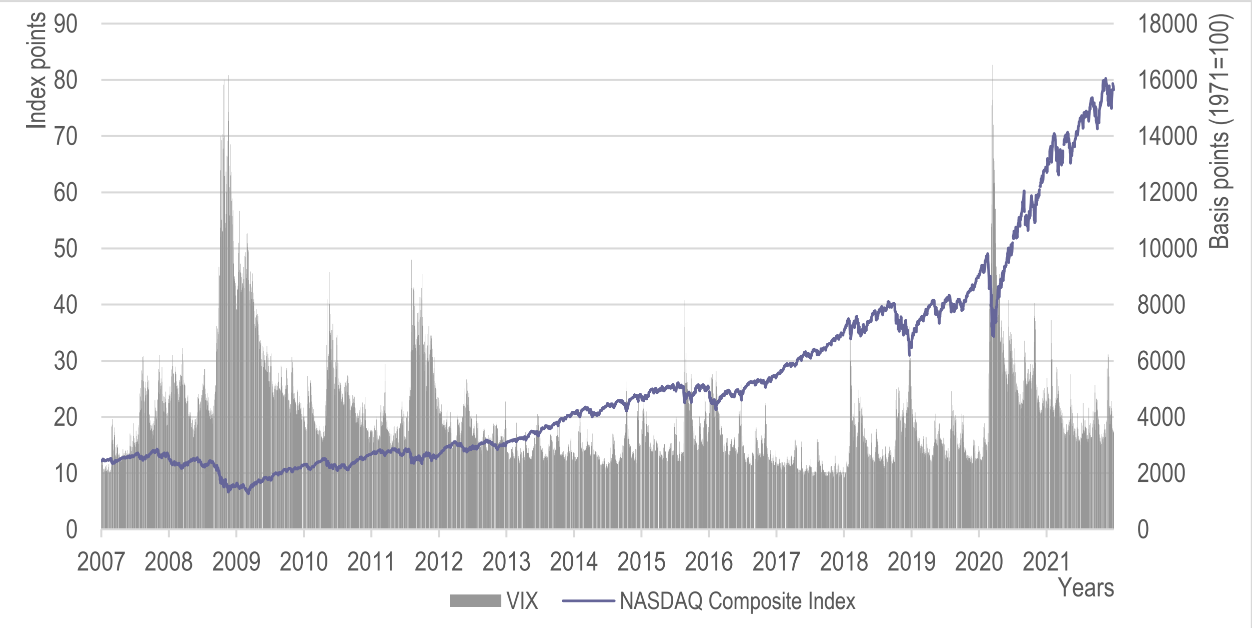

Figure 3. Volatility Index and NASDAQ Composite Index 2007-2021
Source: Merila (2022c); figure created by the author in Excel

The pandemic of 2020 had a forceful impact on the United States equity market: volatility levels skyrocketed in the middle of March, exceeding those seen in previous recessions of October 1987, December 2008, and even in late 1929, the early 1930s (Baker *et al.* 2020). Moreover, the average US stock market price rose 20% from 2018 to the end of 2019, whereas from 2020 to 2021, the S&P 500 index rose 46.3% (see Figure 4). The acceleration in price growth possibly points to the effect of monetary policy actions.

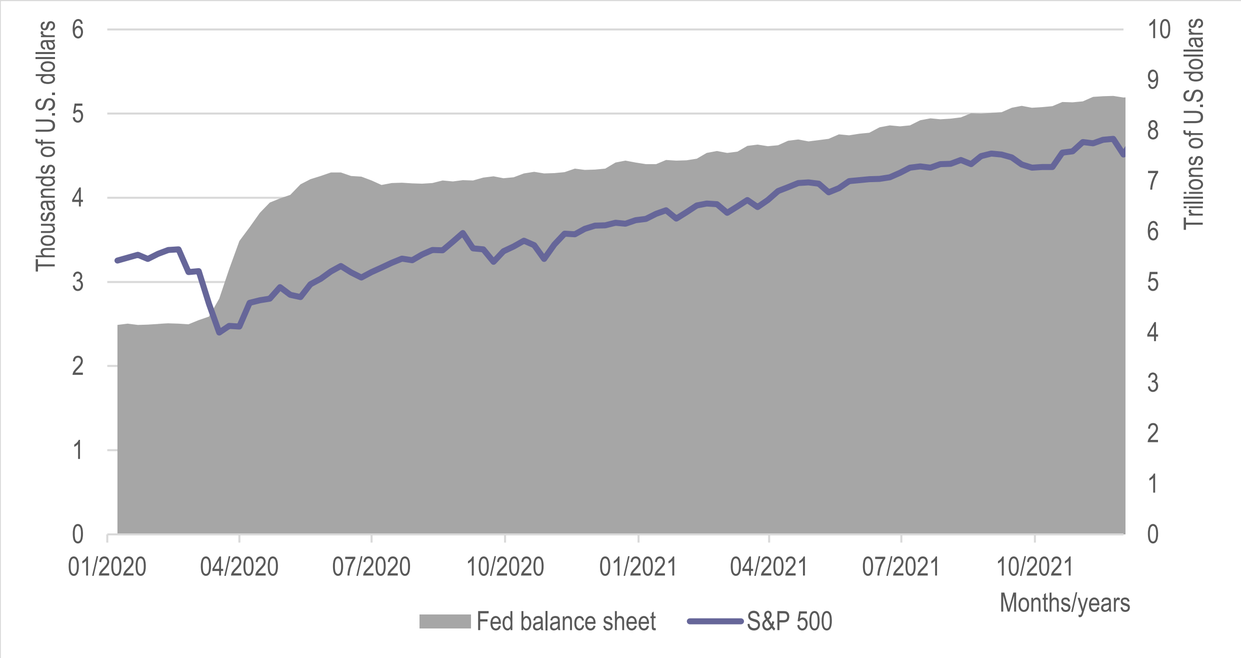

Figure 4. Federal Reserve's assets and S&P 500 index monthly 2020-2021
Source: Federal Reserve Bank of St. Louis; figure created by the author in Excel

Figure 4 shows a sharp decline in the stock prices shortly after the COVID-19 outbreak in the United States and the concurring abrupt increase in the Federal Reserve's assets. However, in the following months, both indicators show continuous lateral growth (see Figure 4). The correlation between the non-stationary Federal Reserve's asset values and S&P 500 index is considered strong (0.7666) by the Cohen's standard (see Appendix 1).

1.3. Quantitative easing impact on financial markets

The monetary policy actions directly impact the financial markets. It is pivotal for monetary policymakers and researchers to understand the relationship between the actual policy transmission mechanisms and the financial markets. (Swanson 2021) In addition, Eksi and Tas (2016) argue that the financial market participants require information about the estimated price reactions to policy measures for effective investment decisions. In the ZLB period, many central banks have resorted to unconventional measures to stimulate the economy, although the impacts of these policies are unclear (Bork 2015; Swanson 2021).

One of the ways the LSAPs are thought to affect the economy is the idea supported by many monetary economists, including James Tobin (1965), Franco Modigliani (1966), Karl Brunner and Allan Meltzer (1963), which is the so-called portfolio balance channel. The main principle of the idea is that all types of financial assets are not perfect substitutes in investors' portfolios for many different reasons. The idea further suggests that supplies of different assets can affect the prices and yields for particular assets. (Bernanke 2012) Bernanke (2012) implies that the Federal Reserve's purchases of mortgage-backed securities should result in a rise in the prices and a decrease in the yields for the securities mentioned above. More importantly to this bachelor's thesis, he suggests that the decrease in mortgage-backed security and Treasury bond yields motivates investors to rebalance their portfolios with other assets – such as stocks – which would cause the prices of those assets to rise.

That is concurrent with the general assumption that quantitative easing works through three main channels: liquidity, signalling, and portfolio balance (Gagnon *et al.* 2010; Krishnamurthy, Vissing-Jorgensen 2011; Neely 2014). When the Federal Reserve limits the supply of illiquid securities, such as the Treasury and mortgage-backed securities, the liquidity premia and spreads in the market shrink for the investors. That drives lenders to offer riskier loans, as the premia from owning illiquid securities is no longer accessible. Investors gravitate towards holding more stocks instead of bonds as the bond yields have decreased. (Mamaysky 2018) In theory, that would cause an increase in demand for stocks and an upsurge in stock prices. (Eksi, Tas 2017) However, many researchers conclude that due to the various aspects of market frictions, it is likely that the price changes associated with portfolio balance flows have a delayed effect (Hou, Moskowitz 2005; Neely 2014; Mamaysky 2018; Swanson 2021).

That presents a question of whether the financial markets experience a change in prices instantaneously or with a lag since it is imperative for proper analysis of the effects of quantitative easing (Mamaysky 2018). Some research has shown that the S&P 500 stock index' volatility reacted to quantitative easing with a lag of several months (Glasserman, Mamaysky 2019). As quantitative easing is practised during a global economic turmoil, the financial markets are affected by numerous variables. The investors not specialised in specific asset classes or investors in asset classes where the impact of quantitative easing was not immediately evident were sluggish to react to the policy changes (Mamaysky 2018).

Given that during the period of quantitive easing the financial markets are affected by different variables, the effect of LSAPs is challenging to differentiate. Several studies have claimed that quantitative easing shifts market expectations about the future federal funds rate (Krishnamurthy, Vissing-Jorgensen 2011; Bauer, Rudebusch 2014), suggesting that even the pure LSAP announcements have significant forward guidance effects (Swanson 2021). That raises the question of whether the investors are reacting to the actual monetary policy or the expectations for the market.

In terms of general monetary policy effects on the economy, Mishkin (2001) argues that the fluctuations caused by policy instruments can affect investments, corporate balance sheets, household wealth and liquidity. The transmission mechanism through which the fluctuations in stock prices change the real economy is the lower cost of capital for firms and credit availability in the market.

1.4. Previously found effects of LSAPs

Attempts to determine the effects of large-scale asset purchasing programs on market interest rates and economic activity have led to many empirical studies in the last decade. The most common research finding is that the LSAPs have significantly lowered various interest rates and spreads. But given the qualitative nature of much of this empirical research, the specific mechanisms through which LSAPs may have influenced the economy is yet unknown. (Gertler, Karadi 2018) There is limited research on the longer-term effects of the unconventional policy conducted in 2020 on the stock market.

Nozawa and Qui (2021) analysed the effects of quantitative easing in 2020 on the financial markets by panel vector autoregressive time series analysis of credit spreads, bond yields and stock returns on FOMC announcement days. On April 9th, they estimated a 24% drop in stock returns attributed to the unconventional monetary policy announcement. However, they did not look into the long-term effects on stock returns. The impact of the pandemic and the following quantitative easing on global and specific financial markets has been researched by some other authors (Alfaro *et al.* 2020; Beirne *et al.* 2020; Caballero, Simsek 2020; Gormsen, Koijen 2020; Landier, Thesmar 2020; Ramelli, Wagner 2020; Zhang *et al.* 2020; Allen 2021; Rebucci *et al.* 2022), but not with a focus on LSAPs in the United States.

From previous data, Eksi and Tas (2017) found that the unconventional policy effect on stock returns increased almost seven times from 2008 to 2016, marking the period of the qualitative easing policies conducted as a response to the 2007-2009 recession. In their research, a heteroscedasticity based empirical methodology was used to examine the impact of LSAPs on investor portfolios. The analysis found that investors sold their Treasury securities to the Federal Reserve during quantitative easing and rebalanced their portfolios with stocks. Their results suggest that Federal Reserve’s monetary policy was one of the driving forces for the booming stock market. Additionally, they conclude that the LSAP program had a much more substantial impact on the stock market than the conventional monetary policy.

Fratzscher *et al.* (2018) analysed the quantitative easing policy impacts on portfolio flows in the US and globally and found significant evidence of rebalancing, particularly in the US equity market. Alpanda and Kabaca (2020) further analysed the portfolio balance effects of the LSAPs internationally. They found that the unconventional monetary policy spillover effects are more significant than those of the conventional monetary policy.

Ferreira and Serra (2022) examined the short-term reaction of European stock and government bonds to the Federal Reserve’s and other central banks’ unconventional monetary policy announcements using a structural VAR method. They concluded that quantitative easing abnormally increased the returns for stocks.

Bernanke (2012) states that LSAPs have appeared to raise the equity market prices by lowering discount rates and stabilising the economy. Consistent with the research conducted by Eksi and Tas (2017) and Ferreira and Serra (2021), Bernanke (2012) implies that it is not a coincidence that the significant spike in US stock prices began shortly after the FOMC decided to increase security purchases substantially.

A working paper by Shah *et al.* (2018) analysed the equity returns in the United States using a structural VAR model and found that their estimates support the hypothesis that quantitative easing shocks greatly impact stock market returns. Their findings suggest a direct effect of the portfolio balance channel on returns of Treasury bonds generated by the LSAP programs in response to the 2007-2009 recession. The results indicate that the quantitative easing shock increased the equity prices by 9.6% by significantly reducing the equity risk premium for the

S&P 500. The same conclusion is found in the Al-Jassar and Moosa's (2019) study on the Federal Reserve's balance sheet growth effects on US stock market returns in the ZLB period using a structural time series model. They conclude that the effect is sizeable but not exclusive.

Many studies support the claim that the balance sheet growth contributes significantly to the economic growth and increase in financial activity. Bork (2015) sought to answer how effective the LSAPs are and found that an unconventional monetary shock significantly decreases the credit spread and improves financial market conditions. The study also found positive responses in industrial production, inflation and employment. The research was conducted using structural VAR analysis. Ijiri and Jinushi (2021) also found using VAR methodology that the Federal Reserve's balance sheet shock had significant expansionary effects on the US economy.

Baumeister and Benati's (2013) working paper using a Bayesian time-varying parameter structural VAR framework concluded that an unconventional monetary policy shock in the US, Euro area, Japan and the UK had a powerful impact on output and inflation. The same was found by Chung *et al.* (2011), who state that their research results suggest that the Federal Reserve's LSAP program contributed significantly to the financial market's activity. Additionally, it likely helped to counteract expected deflation.

Gambacorta *et al.* (2014) examined using a structural VAR model the shock of central bank balance sheet on output and inflation in eight advanced economies, finding that an exogenous increase in the central bank's balance sheet in ZLB leads to a temporary increase in economic activity and the price level. They conclude that the qualitative response in the price level is weaker and less persistent than the effects of interest rate shocks. They add that the price reaction has varied effects in studied countries, with changes in the US having an average lag of 3 months and a duration of 18 months.

A remarkable share of the research on the topic is executed using intraday data. For example, a study conducted by Wright (2012) using a reduced-form daily VAR event-study method found evidence of initial overreaction of markets to the FOMC announcements of quantitative easing actions. Corbet *et al.* (2019) also used a high-frequency event study to examine changes in the US stock market volatility. They determined a short-term positive reaction from investors after announcing unconventional monetary actions.

Opposing that, Mamaysky (2018) showed using an OLS regression that the prices of stocks reacted to quantitative easing announcements over several weeks. They claim that focusing only on the common intraday or two-day windows around the LSAP announcements does not suffice in finding the effects of quantitative easing on bond-like asset classes.

Monetary economics does not have one single policy variable (Leeper *et al.* 1996). Generally, quantitative easing is explained through either Federal Reserve's balance sheet growth, FOMC announcements, the shadow interest rate by Wu and Xia (2016) or the 3-month Treasury bond yield. In the case of Lima *et al.* (2016), monetary aggregates were used to illustrate the impact of quantitative easing instead of the Federal Reserve balance sheet change. In the paper, research indicated that in a ZLB period, from 2008 to 2014, the increase in money supply had a positive and highly significant impact on the stock market. More research (Flannery, Protopapadakis 2002) indicates a vital link between the growth in money aggregates and the stock market.

D'Amico and King (2013) explored the effects of supply change of government debt and its impact on Treasury yields. They found that the quantitative easing measures made in 2009 were responsible for an average yield decreasing periodically by 30 basis points. They refer to the downward shift as the „stock effect", where investors switched from bonds to stocks in their portfolios, concurrent with the theory of portfolio balance channel. Meaning and Zhu (2011) reached the same conclusion. Research by Doh (2010) also supports the notion that unconventional monetary actions at ZLB impacted the prices of traded securities, decreasing Treasury bond yields by decreasing term premia in long-term bond yields and potentially causing a rise in stock prices.

2. METHODOLOGY

The following chapter gives an overview of the methodology used to determine the impact of large-scale asset purchases on the United States stock market. The chapter includes a description of the data used, the model's specifications and a results interpretation guide.

2.1. Data

The analysis is based on the quantitative easing policies made after the COVID-19 outbreak, starting from March 2020. To analyse the effect of monetary policy shocks on the stock market, weekly data is used from 2020 to 2021, resulting in 104 data points. All the mentioned data is from the freely accessible Federal Reserve Bank of St. Louis economics database, also known as FRED. The data can be found in online spreadsheets linked in the list of references of this thesis.

As mentioned in the previous chapter, the LSAPs can be measured by many different variables. In this bachelor's thesis, the variable used is Federal Reserve's balance sheet on the Wednesday level. The balance sheet measures the purchases made by the Fed, resulting in an expansion in the assets, liabilities and money supply in the economy. As seen in Figure 2, the balance sheet had an upsurge in the months of quantitative easing from March 2020 and steadily remained growing.

There is some critique for using the balance sheet as a proxy for quantitative easing. The potential problem stems from investors reacting to the large-scale asset purchase at the announcement, not at the increase in money supply or portfolio balance channel. LSAP announcements act as forward guidance, which imposes a problem on analysing the impact of the balance sheet change. (Wright 2012; Eksi, Tas 2017) This paper follows the works of Uhlig (2005), Gagnon *et al.* (2011), Gambacorta *et al.* (2014), Eksi, Tas (2017) and Al-Jassar, Moosa (2019), who use the balance sheet as a proxy for similar works.

The indicator used for representing the United States stock market is the stock market index Standard and Poors' 500 (hereinafter S&P 500), which includes 500 of the US leading public companies covering approximately 80% of the available market capitalisation (S&P 500 ...). In previous studies on this topic, S&P 500 has been used by many other authors as a basis for the stock market movements (Bork 2015; Farmer 2015; Eksi, Tas 2017; Shah *et al.* 2018; Al-Jassar, Moosa 2019; Corbet *et al.* 2019; Swanson 2021).

Other explanatory variables in the analysis are the federal funds effective rate (Bernanke, Kuttner 2005; Bork 2015; Neely 2015; Uhlig 2005), the US gasoline price (Neely (2015) makes use of the US oil prices, Wu, Xia (2016) include many variables from the energy sector), the 15-year conforming mortgage rate (Flannery, Protopapadakis (2002), Bork (2015), Wu, Xia (2016) all use housing starts or new home sales in their analysis, and Meaning, Zhu (2011) include the 30-year mortgage rate in their model) and the Treasury 2-year bond yield (all these authors – Bernanke, Kuttner (2005), Gagnon *et al.* (2011), D'Amico, King (2013), Bork (2015), Neely (2015), Shah *et al.* (2018), Nozawa, Qui (2021), Swanson (2021) – include Treasury bond yields in their analysis). The model lacks consumer price and inflation variables, but the model was nevertheless constructed successfully in the absence of necessary weekly frequency data. Table 1 shows a statistical summary of the previously mentioned data in the model.

Table 1. Summary statistics (104 observations)

	Mean	Std. deviation	Minimum	Maximum	Coef. of variation
S&P 500	3749	607	2398	4793	0.162
Federal assets	7233000	1238000	4146000	8790000	0.171
Federal funds rate	0.215	0.417	0.040	1.590	1.940
Gasoline price	1.594	0.545	0.438	2.494	0.342
Mortgage rate	2.555	0.237	2.225	3.218	0.093
2-year T-bond yield	0.374	0.364	0.125	1.626	0.973

Source: Merila (2022f); author's calculations

The S&P 500 is index-point based and measured daily at market close. The stock market index is a modification of the Laspeyres index to calculate the change in stock prices: the company's market capitalisation is divided by a proprietary value of numerous stock-affecting variables (S&P Dow ... 2022). The Federal Reserve balance sheet is measured in millions of US dollars and updated weekly, on a Wednesday level. The federal funds effective rate is presented daily in percentages. The US gasoline price is priced at dollars per gallon, and the 15-year conforming mortgage rate index is calculated from actual mortgage transactions nationwide. The two latter and the 2-year Treasury bond yield data are available daily.

All the daily-occurring data was transformed into weekly data frequency. The data is composed, tested and analysed using the software programmes Excel, Gretl and RStudio. First, the initial data cleaning and organising are completed in Excel, following a data examination and testing in RStudio. Next, the correlation between variables and their significance is calculated in Excel. Finally, the testing of the VAR model and structural analysis is performed in Gretl and RStudio.

The data is tested for stationarity using a Kwiatkowski, Phillips, Schmidt and Shin (hereinafter KPSS) unit root test and an Augmented Dickey-Fuller (hereinafter ADF) test. The presence of a unit root determines whether the time series has either a stochastic or a deterministic trend (Phillips, Perron 1988). For this analysis, the data is preferred not to have any trends, and this is tested using a KPSS test. Additionally, a time series is considered stationary if it satisfies the conditions of a constant mean and time-invariant variance and covariation (Granger, Newbold 1974), which is tested for by the ADF test. The hypothesis of stationarity of an autoregressive unit root test such as ADF can only be accepted when the hypothesis of an existing unit root is rejected (Hobijn *et al.* 2004). Therefore, the data is first tested for a unit root using a KPSS test, followed by the ADF test.

2.2. Model specifications

Monetary policy shock's impacts and relationships to other economic variables are typically assessed using a structural vector autoregression model (Leeper *et al.* 1996; Stock, Watson 2001; Kotzé 2021b). VAR models are extensively used in the time series analysis because they allow the examination of variables that interact (Stock, Watson 2001). Additionally, vector autoregression provides an efficient forecasting tool, and it is used by most policy-making institutions and researchers of macroeconomics (Kotzé 2021b).

In a univariate autoregression, a time series variable can be modelled as dependent on its own lagged values. A vector autoregression is the natural multivariate extension to the univariate autoregression, where variables can be modelled by being additionally dependent on the lags of other variables in the analysed vector. (Stock, Watson 2001; Schenck 2016) As an extension, a structural vector autoregressive model allows to model the contemporaneous relationships between variables (Stock, Watson 2001; Kotzé 2021b).

A simple VAR model is a reduced form model, making the analysis using impulse responses challenging to interpret. The impulse response function is helpful for structural VAR analysis, uncovering the relationships between variables and their responses to specific shocks. However, in the case of a simple VAR, it is not often evident which set of impulse responses accurately reflects the investigated macroeconomic effect. (Lütkepohl 2005) This is why a structural VAR method is most commonly used (Stock, Watson 2001).

The structural vector autoregression model was popularised by Christopher Sims (1980) in his research paper „Macroeconomics and reality" and has been a consistent and credible method for data description, forecasting and structural analysis (*Ibid.*). An SVAR model identifies the relationships by setting restrictions on the impacts of the variables on one another. A contemporaneous impact matrix implements the restrictions. (Bernanke 1986; Blanchard, Watson 1986; Sims 1986; Stock, Watson 2001) The restrictions can be zero or sign restrictions or a combination of the two (Uhlig 2005).

The current bachelor's thesis uses zero restrictions on the contemporaneous impact matrix to identify the balance sheet shock. The resulting model has been used for analogous research before by Bagliano, Favero (1998), Bernanke, Kuttner (2005), Lütkepohl (2005), Wright (2012), Eickmeier, Hofman (2013), Gambacorta *et al.* (2014), Bork (2015), Bowman *et al.* (2015), Shah *et al.* (2018), Beirne *et al.* (2020), Ijiri, Jinushi (2021) and Ferreira, Serra (2022). Including these additional zero restrictions improves identification by reducing the number of appropriate impulse responses, provided the restrictions are suitable (Uhlig 2005).

A structural VAR model is employed to study the impact of unconventional monetary policy on the US stock market. To estimate the SVAR model, first, a benchmark reduced form VAR model is constructed:

$$Y_t = B_k Y_{t-k} + u_t, \tag{1}$$

where

Y_t – vector of observable endogenous macroeconomic variables (i.e. S&P 500, Federal Reserve's assets, federal funds effective rate, US gasoline price, mortgage rate index and 2-year Treasury bond yield),

B_k – matrix of autoregressive coefficiants of finite-order lag values of Y_t,

k – the number of lags,

u_t – the vector of white noise (residual errors),

and deterministic terms (constant) are excluded from this VAR model.

The structural form of the benchmark VAR model is the following:

$$AY_t = B_k Y_{t-k} + \varepsilon_t, \tag{2}$$

where

A – the contemporaneous relationship matrix between variables, and

ε_t – the model's error terms that describe the mutually uncorrelated structural shocks, where the mean is zero, and they will be assumed to be normally distributed.

The structural shocks are related to the reduced form residual errors as follows:

$$u_t = A^{-1}\varepsilon_t \tag{3}$$

Zero restrictions are imposed on the impulse responses of US gasoline prices, federal funds rate, mortgage rate index and 2-year Treasury bond yield in response to the unconventional monetary policy shock (see Table 2). The shock is demonstrated by a one standard deviation increase in the Federal Reserve's balance sheet and is assumed to affect the stock market.

Table 2. Contemporaneos impact matrix

	S&P 500	Gasoline price	Federal funds rate	Mortgage rate	2-year T-bond yield	Federal assets
Balance sheet shock	?	0	0	0	0	?

Source: created by the author following previous studies (Sims 1986; Uhlig 2005; Gambacorta *et al.* 2014; Shah *et al.* 2018; Beirne *et al.* 2020)

Therefore, to answer the primary research question about the stock market volatility response to the policy shock, no restrictions are imposed on the S&P 500 market index. The restriction estimates only the unconventional monetary policy shock response without imposing the responses from conventional monetary policy and other macrovariables (Gambacorta *et al.* 2014). Furthermore, the restrictions are set on impact, meaning that the shock is assumed to have no impact on the respective variable in the impact period of the shock.

The model is tested for residual heteroskedasticity using an ARCH-LM test and autocorrelation on a selected lag length applying a Portmanteau and a Durbin-Watson test. Robert Engle's ARCH-LM test was selected for its ability to test multivariate heteroskedasticity: it is an extension to the Lagrange multiplier test with the added ability to test for autoregressive conditional heteroskedasticity (ARCH) effects. (Hacker, Hatemi-J 2005) The Portmanteau test is used for multivariate autoregressive processes, and it tests for correlations between residual errors (Hosking 1980). For achieving the optimal results using time series analysis, the residuals are assumed to be normally distributed. Residual normality is tested using a Doornik-Hansen test, designed to test normality in multivariate models (Doornik, Hansen 2008). The VAR model is additionally tested for inverse polynomial roots' dynamic stability up to the selected lag length.

2.3. Analysis interpretation

In addition to the SVAR model, the data is examined by applying a correlation analysis method. Correlation allows to assess the strength, direction and statistical significance of a linear relationship between two variables. The analysis entails the estimation of a sample correlation coefficient ranging from one to minus one and its significance when applied to the population set. (Introduction ... 2013) The Cohen's standard for effect size states the correlation coefficients between 0.1 and 0.3 show a weak correlation, between 0.3 and 0.5 a medium correlation, and a coefficient over 0.5 represents a strong correlation (Cohen *et al.* 2003).

The structural analysis of VAR models is primarily based on impulse responses, forecast error variance decompositions and Granger-causality tests. Although VAR is based on ordinary least squares regression, the typically estimated regressions coefficients or R^2 statistics are left unreported because IRFs, FEVDs and Granger-causality provide much more insight (Stock, Watson 2001).

Granger-causality statistics explore whether lags of one variable explain the values of other variables (*Ibid.*). In other terms, it can test whether the past values of the Federal balance sheet can explain the movements of the stock market and other explainatory variables. The impulse response function shows the effect of a positive one standards deviation shock in one variable on another (*Ibid.*). In the case of the first difference variables, the function comprises accumulated responses (Stock, Watson 2018).

The forecast error decomposition shows the variance in percentages of the errors in forecasting. Specifically, the FEVD shows the forecasting error in variables impacted by a specific shock over time. It helps to understand how much variability is explained by the dependent variable's own variability compared to the impact of other variables. (Stock, Watson 2001)

Impulse responses are typically presented on a figure. The X-axis shows the duration in time from the impact of the shock, the Y-axis shows the change in the unit of measurement, and confidence intervals are placed over the function as +/- 2 standard deviation confidence bands (which is equivalent to the confidence level of 95 per cent). Forecast error decompositions are presented as stacked graphs, where the X-axis shows time and the Y-axis the percentage of variation.

3. EMPIRICAL ANALYSIS

This chapter gives an overview of the analysis results on the effects of large-scale asset purchases on the stock market. The analysis methods used in this chapter are correlation, impulse response function of the structural VAR model, Granger-causality, and forecast error decomposition.

3.1. Empirical tests and correlation analysis

Given the previously conducted studies on the subject, the hypothesis for this analysis was that the sudden increase in the Federal Reserve’s balance sheet gets a positive response or no statistically significant response from the stock market. The structural VAR model (2) estimated in the previous chapter is used for the empirical analysis.

Firstly, the extracted data is tested for stationarity using a KPSS test, which rejects the null hypothesis of stationarity in all the analysed time series’ (see Appendix 3). Therefore, the variables are differentiated to achieve the desired stationarity for time series modelling. The differentiating achieved the desired stationarity as seen from the following KPSS and ADF tests (see Appendix 4 and 5).

Secondly, the VAR model is constructed using a lag value of four. In the lack of previous works conducted with weekly data frequency and the lack of works on the observed time period, the lag selection follows Akaike information criterion (hereinafter AIC) criteria recommendations. A few different lag-length models are tested, with the selected four-lag model attaining the highest log-likelihood value and lowest AIC criteria value. The lag length of a month is concurrent with the previously conducted research on quantitative easing by Mamaysky (2018) and Glasserman, Mamaysky (2019), which suggest that the unconventional monetary policy has a delayed effect from several weeks to several months.

The constructed VAR model is tested for heteroskedasticity using an ARCH-LM test, which confirms homoskedasticity at the lag-length four. The model is additionally checked for autocorrelation and normality of the residuals. The Portmanteau test shows no autocorrelation at lag order four, and the Doornik-Hansen test confirms the normality of errors. The Durbin-Watson test statistic also supports the assumption of no autocorrelation. The results of the abovementioned tests can be found in Appendix 6. As no constant is included in the model, the residuals are assumed to have a mean of zero. Calculations support that assumption. The VAR model has no inverse polynomial roots outside the unit circle, i.e. all eigenvalues are smaller than 1 (see Appendix 7), confirming the dynamic stability of the model.

The correlation matrix is composed of stationary first difference variables (see Table 3). The significance of the correlation coefficients is shown in the Table 4.

Table 3. Correlation coefficients

	S&P 500	Federal assets	Federal funds rate	Gasoline price	Mortgage rate	2-year T-bond yield
S&P 500	1.0000	-	-	-	-	-
Federal assets	-0.0098	1.0000	-	-	-	-
Federal funds rate	0.3098	-0.3845	1.0000	-	-	-
Gasoline price	0.5847	-0.2109	0.2975	1.0000	-	-
Mortgage rate	-0.2279	-0.0219	-0.0834	-0.0805	1.0000	-
2-year T-bond yield	0.1849	-0.3013	0.3342	0.1749	0.5944	1.0000

Source: Merila (2022f), author’s calculations

The matrix shows a moderately strong correlation between the gasoline price and the stock market (0.5847) and a medium correlation between the federal funds rate and the stock market (0.3098). In addition, there is an expected negative correlation between the federal funds rate and the Federal Reserve’s assets (-0.3845). Next, the statistical significance of the correlation coefficients is calculated, and the respective p-values are presented in Table 4.

Table 4. Correlation coefficients' statistical significance

	S&P 500	Federal assets	Federal funds rate	Gasoline price	Mortgage rate	2-year T-bond yield
S&P 500	1.0000	-	-	-	-	-
Federal assets	0.9219	1.0000	-	-	-	-
Federal funds rate	0.0015	6.07·10^(-5)	1.0000	-	-	-
Gasoline price	8.85·10^(-11)	0.0325	0.0023	1.0000	-	-
Mortgage rate	0.0206	0.8259	0.4025	0.4189	1.0000	-
2-year T-bond yield	0.0616	0.0020	0.0006	0.0773	3.59·10^(-11)	1.0000

Source: Merila (2022f); author's calculations
Note: Null hypothesis is that correlation is not statistically significant on a population level

There is no statistically significant correlation between the differentiated values of the Federal Reserve's assets and the S&P 500 (see Table 4). The 2-year Treasury bond yield and the stock market show a weak positive correlation (0.1849) (see Table 3), which is not concurrent with the portfolio balance channel theory.

3.2. Structural analysis

As explained in the previous chapter, the structural analysis in this bachelor's thesis involves employing a Granger-causality test, assessing impulse response function figures, and forecasting error decomposition results. The SVAR model is comprised of four lags, meaning the model is dependent on values up to one month ago.

The Granger-causality statistic shows that the balance sheet shock does Granger-cause any of the endogenous variables, including the stock market volatility, on a 90% confidence level (see Appendix 6). This result shows that the past movements, in this case – the increase of the Federal Reserve's assets, can explain the stock market's and other variables' movements.

Since the variables are introduced into the model as first differences, the impulse response function has been constructed as cumulative. As a result, the impulse response figure for the stock market in response to an unconventional monetary policy shock (see Figure 5) shows a 17 index point increase after one standard deviation positive shock in Federal Reserve's balance sheet by the first week.

After the first week, impact momentum gradually declines, and the response is statistically significant until the fourth week (see Figure 5). Finally, the impulse response returns to the pre-shock state by the second month, suggesting a substantial short-term positive impact but no long-term effects of unconventional monetary policy on the stock prices.

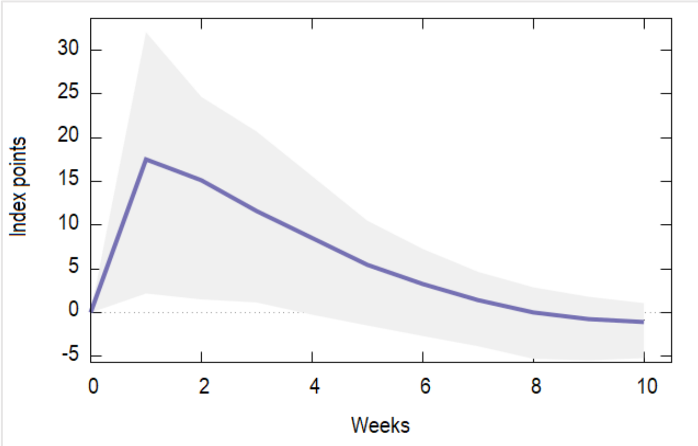

Figure 5. Impulse reaction function of S&P 500 to the unconventional monetary policy shock
Source: figure created by the author in Gretl on the model provided in Appendix 6

One explanation for the short-term positive effect could be the forward guidance implications of the asset purchase programs, which fuel the investors' positive future expectations short-term, increasing the equity market's activity and prices. These results confirm the author's hypothesis that stock market reacts positively to a Federal Reserve's balance sheet shock and are concurrent with other studies (Wright 2012; Lima *et al.* 2016; Eksi, Tas 2017; Shah *et al.* 2018; Al-Jassar, Moosa 2019, Corbet *et al.* 2019) that also found a significant positive effect on the equity market. However, as seen in Figure 5, these results point to an initial overreaction in the stock market.

The unconventional monetary policy shock had a minor negative, statistically insignificant short-term effect on the 2-year Treasury bond yield (see Appendix 8) and no long-term effect. Moreover, the US gasoline price was only imperceptibly affected, rising 0.015 dollars per gallon by the first week of impact and the overall policy effect lasted for two months. The mortgage rate fell 0.05 percentage points on account of quantitative easing, though the effect was statistically insignificant. The impact lasted up to five weeks.

The forecast error decomposition figure (see Figure 6) shows which variables explain the dependent variable's variance over the ten weeks after the impact of unconventional monetary policy. The figure illustrates the variance of the S&P 500, and it shows that the 2-year Treasury bond yields and the federal funds rate's variability both explain about 10 per cent of the stock market's variance on the first week of impact.

The forecast error decomposition (see Figure 6) shows a minimal effect of the Federal Reserve's assets variance on the stock market's variability until the second week and a slight increase in the fourth week and onwards. The mortgage rate's impact increases by about seven percentage points in the third week. From the fifth week, about 50 per cent of the S&P 500's variability is explained by other variables in the model. This forecast error decomposition suggests that most of the variance in the S&P 500 is explained by its own variance, and the Federal Reserve's balance sheet has minimal effects on it.

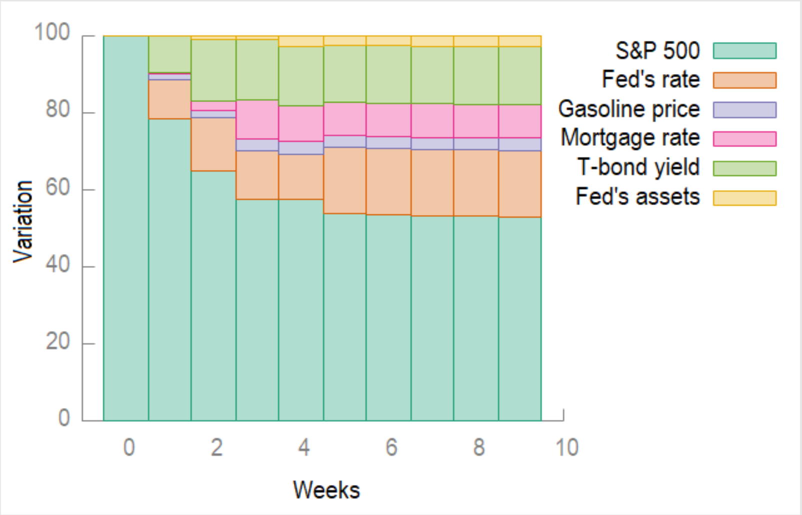

Figure 6. Forecast error decomposition for S&P 500
Source: figure created by the author in Gretl on the model provided in Appendix 6

The Federal Reserve's balance sheet's variance is mainly explained by the federal funds rate's variability (see Appendix 9): it explains almost 20 per cent on impact. It reaches over 50 per cent by the third week. The Treasury bond yield is also explained mainly by the variability of the Fed's rate, followed by the mortgage rate's impact.

As seen in Appendix 9, the stock market variability has a significant 16 per cent effect on the US gasoline price variance. The federal funds rate's variance is also impacted by the stock market, with its variance explaining over 10 per cent by the first week. Fed's rate variability is additionally explained by the 2-year Treasury bond yield (about 20 per cent by the third week) and mortgage rate (about 15 per cent by the third week).

3.3. Discussion

The findings of this paper conclude that the unconventional monetary policy actions by the US Federal Reserve affect the stock market only short-term, and no long-term effects were found. Therefore, there is no evidence suggesting asset purchase's involvement in the rapid long-term increase of prices in the equity market. On the other hand, there is evidence to conclude that quantitative easing acts as solid forward guidance and an indicator of future market conditions. These findings are consistent with the claims of Krishnamurthy, Vissing-Jorgensen (2011), Bauer, Rudebusch (2014) and Swanson (2021).

The simultaneous increase in the equity prices, and the decrease in the Treasury bond yield, point to investors' decisions to rebalance their portfolios by selling bonds and purchasing stocks. This is evidence of the portfolio balance channel effect expressed by the impulse reactions of Treasury bond yield and the stock market from the balance sheet shock. Similar effects were found by Fratzscher *et al.* (2018) and Eksi, Tas (2017) from previous quantitative easing programmes. However, in this thesis, the decrease in Treasury bond yield is statistically insignificant. Furthermore, the potential effect only lasts up to four weeks.

Other explanations point to a generally short-term impact of the unconventional monetary policy on the stock market. This conclusion contradicts the findings of Shah *et al.* (2018), Leeper *et al.* (1996), Al-Jassar, Moosa (2019) and Ferreira, Serra (2022), who found a lingering long-term effect. Nevertheless, the other short-term analysis studies (Wright 2012; Corbet *et al.* 2019) support the notion of only a short-term positive impact.

The contradictory results may indicate a vast macroeconomic difference between the financial markets of 2008-2019 and 2020-2022 explained by variables other than the quantitative easing, changing how the unconventional monetary policy affected the equity market. Moreover, the results may be skewed by oscillating reactions from the investors: the initial drop in the equity returns found by Nozawa and Qui (2021) could have affected the impulse reaction results, minimising the extent of the positive reaction.

Future research could analyse the effects of unconventional monetary policy using a monetary aggregate as a proxy for large-scale asset purchases. Using a monetary aggregate as a proxy allows to examine the effect of a rapid increase in the money supply effects on financial markets. That would allow the modelling of the specific transmission mechanism of quantitative easing on the markets with the assumption that the main effect of the large-scale asset purchases is money creation (Bork 2015; Gertler, Karadi 2018; Al-Jassar, Moosa 2019; Swanson 2021) without forward guidance effects. This constructed model would only be possible in monthly or longer data frequencies, allowing the possibility of investigating the long-term effects.

Additionally, a Bayesian analysis of the structural VAR model could be used instead of the classical VAR model since Bayesian models require no loss of degrees of freedom, therefore less data length for analysis. Moreover, the Bayesian approach makes it easier to incorporate sign restrictions, which provide more accuracy in results. (Kotzé 2021a) This technique could be more beneficial for determining the 2020-2021 quantitative easing effects with a monthly frequency dataset.

The restrictive weekly frequency limited this research in including vital explanatory variables in the model, such as inflation and other macroeconomic variables that affect the financial markets. The author suggests including the gross domestic product or purchasing power parity, consumer price index, industrial production, unemployment rate and housing starts in future studies. These variables directly affect the equity market, and including these would provide additional precision to the analysis.

CONCLUSION

This bachelor’s thesis aimed to explore the impact of the US Federal Reserve’s asset purchase programme for 2020-2021 on the United States stock market. The author hypothesised that the large-scale asset purchases had a positive or no effect on equity prices. The findings suggest a short-term positive effect from the quantitative easing on the stock market but no long-term effects.

The research was conducted using a structural VAR model and weekly frequency data from the Federal Reserve of St. Louis economics database. The proxy chosen for quantitative easing policies was the Federal Reserve’s balance sheet and S&P 500 for the stock market. Other variables in the model were the federal funds effective rate, the US gasoline price, the 2-year Treasury bond yield and the 15-year mortgage rate index. All of the variables were differentiated for achieving the desired stationarity for time series modelling. The model was constructed to have four lags and had no indication of autocorrelation, heteroskedasticity or deviation from residual normality.

Correlation analysis for the non-stationary non-differentiated variables showed a statistically significant strong correlation between quantitative easing and the stock market. However, the once-differentiated Federal balance sheet and S&P 500 used for the finalised model showed no significant correlation.

The structural analysis examined impulse reaction functions, forecast error decompositions and Granger-causality. The impulse reaction figure for the impact of quantitative easing on the stock market showed an initial overreaction in the equity prices with a 17 index point increase by the first week after the balance sheet shock. On the other hand, the forecast error decomposition demonstrated a minimal effect of the Federal balance sheet’s variability on the stock markets variance. Nevertheless, analysis established a Granger-causation of quantitative easing on the stock market and other explanatory variables on a 90 per cent confidence level.

Findings suggest a limited but sizable effect of the unconventional monetary policy on the equity market, partially confirming the author's hypothesis. However, the found results contradict some of the previous works on the topic related to the quantitative easing policies from 2009 to 2015. This inconsistency may indicate a difference in the financial market composition in these time periods and point to different quantitative easing transmission mechanisms affecting the stock market.

To find the possible long-term effects in the future, the author suggests using a monthly data frequency with monetary aggregates as a proxy for the unconventional monetary policy to model the substantial increase in the money supply in the financial markets as another specific transmission mechanism. In further studies of the subject, a Bayesian structural VAR model would give additional accuracy in defining the macroeconomic relationships between variables (Kotzé 2021a).

The author suggests monthly frequency data for including additional strictly monthly-frequency explanatory variables such as gross domestic product or purchasing power parity, industrial production, unemployment rate, housing starts, and consumer price index or inflation rate. These variables directly affect the financial markets, and including these would provide additional precision to the analysis.

KOKKUVÕTE

KVANTITATIIVSE LÕDVENDAMISE MÕJUD AMEERIKA ÜHENDRIIKIDE AKTSIATURULE COVID-19 PANDEEMIA AJAL

Li Merila

Käesoleva bakalaureusetöö eesmärgiks oli uurida USA Föderaalreservi 2020-2021 aastal tehtud varaostuprogrammi mõju USA aktsiaturule. Autori hüpoteesiks oli, et suuremahulistel varaostudel oli positiivne või statistiliselt mitteoluline mõju aktsiahindadele. Analüüsi käigus saadud tulemustest selgus, et antud kvantitatiivsel lõdvendamisel oli positiivne lühiajaline mõju aktsiahindadele, aga pikaajaline mõju puudus.

Analüüsimeetodina kasutati antud töös strukturaalset VAR mudelit ja nädalase sagedusega andmeid, mis pärinesid Föderaalreservi majandusandmete andmebaasist. Kvantitatiivse lõdvendamise näitajana kasutati Föderaalreservi bilansimahtu ja USA aktsiaturu näitajana S&P 500 aktsiaindeksit. Teiste selgitavate näitajatena lisati mudelisse reaalne föderaalreservi intressimäär, USA bensiinihind, 2-aastase riigivõlakirja intressitulu ja 15-aastase kodulaenu indeks. Kõiki loetletud näitajaid diferentseeriti, et saavutada eelistatud statsionaarsus aegridade modelleerimiseks. Mudel koostati nelja viitajaga ning testimiste tulemused näitasid, et antud viitaja puhul ei esinenud autokorrelatsiooni, heteroskedastiivsust ega kõrvalekaldumist jääkliikmete normaaljaotusest.

Korrelatsioonianalüüs näitas mittestatsionaarsete mittediferentseeritud näitajate puhul statistiliselt olulist tugevat korrelatsiooni kvantitatiivse lõdvendamise ja aktsiaturu vahel. Diferentseeritud näitajate puhul ei esinenud Föderaalreservi balansimahu ja S&P 500 puhul statistiliselt olulist korrelatsiooni.

Tehtud strukturaalne analüüs uuris impulsireaktsioonifunktsioone, prognoosivigade dekompositsioone ja Grangeri põhjuslikkust. Impulsireaktsioonide graafikud kvantitatiivse

lõdvendamise mõjust aktsiaturule näitasid esialgset ülereageerimist turul, kus esimese nädalaga pärast Föderaalreservi balansimahu šokki tõusid aktsiahinnad 17 indekspunkti. Prognoosivigade dekompositsioonigraafik näitas aga, et bilansimahu variatsioon mõjutas aktsiaturu variatsiooni vaid minimaalselt. Sellegipoolest kinnitas Grangeri põhjuslikkuse test 90-protsendilisel usaldustasemel, et kvantitatiivne lõdvendamine põhjustab aktsiaturu ja teiste selgitavate tunnuste muutust.

Uuringu tulemused viitavad, et mittekonventsionaalsel rahapoliitikal oli piiratud, kuid märkimisväärne mõju aktsiaturule, osaliselt kinnitades autori hüpoteesi. Leitud tulemused on vastuolus mõnede varasemate uuringutega, mis käsitlevad kvantitatiivse lõdvendamise poliitikat aastatel 2009 kuni 2015. See ebakõla võib viidata laiemale finantsturgude seisu erinevusele nendel ajaperioodidel ja osutada teistsugustele kvantitatiivse lõdvestamise mõjumehhanismidele, kui antud töös käsitletud.

Võimalike pikaajaliste mõjude leidmiseks soovitab autor tulevastes töödes kasutada kuist andmesagedust ning mittekonventsionaalse rahapoliitika näitajana rahaagregaate, et modelleerida rahapakkumise olulist suurenemist finantsturgudel kui spetsiifilist mõjumehhanismsi. Edasistes uuringutes annaks Bayesi strukturaalse VAR mudeli kasutamine täiendava täpsuse muutujatevaheliste makromajanduslike seoste määratlemisel (Kotzé 2021a).

Autor soovitab kasutada kuist andmesagedust, et võimaldada täiendavate oluliste selgitavate muutujate lisamist, mis on kättesaadavad vaid kuise sagedusena. Mudelisse võiks lisada sisemajanduse kogutoodangu või ostujõu pariteedi, tööstustoodangu mahu, töötuse määra, uute eluasemete valmimise mahu ja tarbijahinnaindeksi või inflatsioonimäära. Need muutujad mõjutavad otseselt finantsturge ja nende kaasamine annaks analüüsile samuti täiendava täpsuse.

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APPENDICES

Appendix 1. Correlation matrix for non-stationary variables

	S&P 500	Federal assets	Federal funds rate	Gasoline price	Mortgage rate	2-year T-bond yield
S&P 500	1.0000	-	-	-	-	-
Federal assets	0.7666	1.0000	-	-	-	-
Federal funds rate	-0.2739	0.8061	1.0000	-	-	-
Gasoline price	0.9420	0.5986	0.0684	1.0000	-	-
Mortgage rate	-0.5966	-0.8115	0.7237	-0.4225	1.0000	-
2-year T-bond yield	-0.0613	-0.6028	0.8920	0.0977	0.7393	1.0000

Source: Merila (2022f); author's calculations

Appendix 2. Correlation significance matrix for non-stationary variables

	S&P 500	Federal assets	Federal funds rate	Gasoline price	Mortgage rate	2-year T-bond yield
S&P 500	1.0000	-	-	-	-	-
Federal assets	2.44·10^(-21)	1.0000	-	-	-	-
Federal funds rate	0.0049	5.59·10^(-25)	1.0000	-	-	-
Gasoline price	3.57·10^(-50)	1.92·10^(-11)	0.4903	1.0000	-	-
Mortgage rate	2.35·10^(-11)	1.53·10^(-25)	4.01·10^(-18)	7.93·10^(-69)	1.0000	-
2-year T-bond yield	0.5361	1.29·10^(-11)	5.99·10^(-37)	0.3237	3.21·10^(-19)	1.0000

Source: Merila (2022f); author’s calculations
Note: Null hypothesis is that correlation is not statistically significant on a population level

Appendix 3. KPSS test results for non-differentiated variables

	S&P 500	Federal assets	Federal funds rate	Gasoline price	Mortgage rate	2-year T-bond yield
KPSS level	2.051	1.714	0.695	1.764	1.258	0.470
p-value	0.010*	0.010*	0.014	0.010*	0.010*	0.048

Source: Merila (2022f), author's calculations
Note: 1. *smaller than the printed value
2. Null hypothesis: the variables are stationary

Appendix 4. KPSS test results for first-difference variables

	S&P 500	Federal assets	Federal funds rate	Gasoline prices	Mortgage rate	2-year T-bond yield
KPSS level	0.127	0.304	0.319	0.193	0.425	0.179
p-value	0.100*	0.100*	0.100*	0.100*	0.066	0.100*

Source: Merila (2022f); author's calculations
Note: 1. *bigger than the printed value
2. Null hypothesis: the variables are stationary

Appendix 5. ADF test results for first-difference variables

	S&P 500	Federal assets	Federal funds rate	Gasoline prices	Mortgage rate	2-year T-bond yield
ADF level	-4.874	-3.972	-4.827	-4.147	-4.562	-3.713
p-value	0.010*	0.013	0.010*	0.010*	0.010*	0.027

Source: Merila (2022f); author's calculations
Note: 1. *smaller than the printed value
2. Null hypothesis: the variables are non-stationary

Appendix 6. VAR estimates for S&P 500

	Coefficient	Std. error	T-ratio	P-value	
S&P 500:1	-0.2017	0.1236	-1.6320	0.1069	
S&P 500:2	-0.4029	0.1259	-3.2000	0.0020	***
S&P 500:3	-0.1260	0.1291	-0.9753	0.3325	
S&P 500:4	-0.2596	0.1254	-2.0710	0.0418	**
Federal assets:1	$7.29 \cdot 10^{(-6)}$	0.0002	0.0390	0.9690	
Federal assets:2	0.0003	0.0002	1.6000	0.1137	
Federal assets:3	-0.0002	0.0002	-1.0460	0.2987	
Federal assets:4	0.0003	0.0001	2.0170	0.0473	**
Federal funds effective rate:1	161.3090	185.9590	0.8674	0.3885	
Federal funds effective rate:2	33.0755	214.1500	0.1544	0.8777	
Federal funds effective rate:3	-458.1020	214.0170	-2.1400	0.0356	**
Federal funds effective rate:4	106.0360	191.3420	0.5542	0.5811	
Gasoline price:1	-46.9482	104.6640	-0.4486	0.6550	
Gasoline price:2	190.6830	110.4370	1.7270	0.0884	*
Gasoline price:3	205.7990	110.2880	1.8660	0.0659	*
Gasoline price:4	84.9008	113.7970	0.7461	0.4580	
15-year mortgage index:1	-647.6470	209.6210	-3.0900	0.0028	***
15-year mortgage index:2	-330.5410	224.2420	-1.4740	0.1447	
15-year mortgage index:3	176.0830	213.7000	0.8240	0.4126	
15-year mortgage index:4	-106.8730	215.3930	-0.4962	0.6212	
2-year Treasury bond yield:1	782.9720	208.4840	3.7560	0.0003	***
2-year Treasury bond yield:2	666.1270	225.5430	2.9530	0.0042	***
2-year Treasury bond yield:3	65.2590	251.6930	0.2593	0.7961	
2-year Treasury bond yield:4	-44.2431	251.8170	-0.1757	0.8610	

Note: Confidence level: ***=99%, **=95%, *=90%.

R-squared	0.5511	Adjusted R-squared	0.4134
F (24, 75)	3.8357	P-value (F)	$4.28 \cdot 10^{(-6)}$
rho	0.0208	Durbin-Watson	1.9533

Source: Merila (2022f); author's calculations

ARCH-LM test for heteroskedasticity of lag order 4:

Null hypothesis: heteroskedasticity not present

Test statistic: LM = 1774.326 (df = 1764)

with p-value = 0.4267

Appendix 6 continued

Portmanteau test for autocorrelation for lag order 4:

Null hypothesis: autocorrelation not present

Test statistic: LB = 678.47 (df = 720)

with p-value = 0.8640

Doornik-Hansen test for normality of residuals:

Null hypothesis: residuals are normally distributed

Test statistic: Chi-square(2) = 2.8

with p-value = 0.2466

Granger causality test:

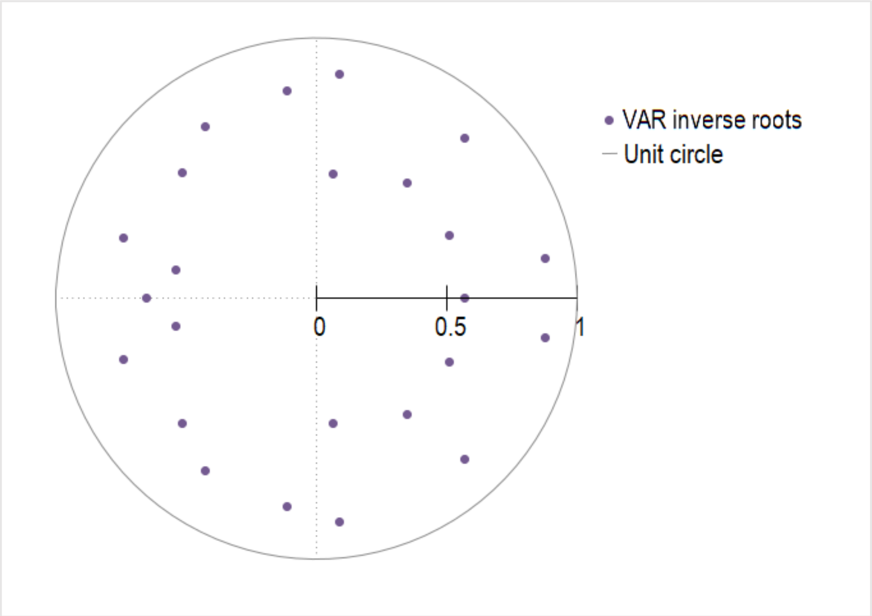
Null hypothesis: Federal Reserve balance sheet shock does not Granger-cause any of the variables included in the Y_t

Test statistic: F-test = 1.4946 (df_1 = 20, df_2 = 450)

with p-value = 0.07812

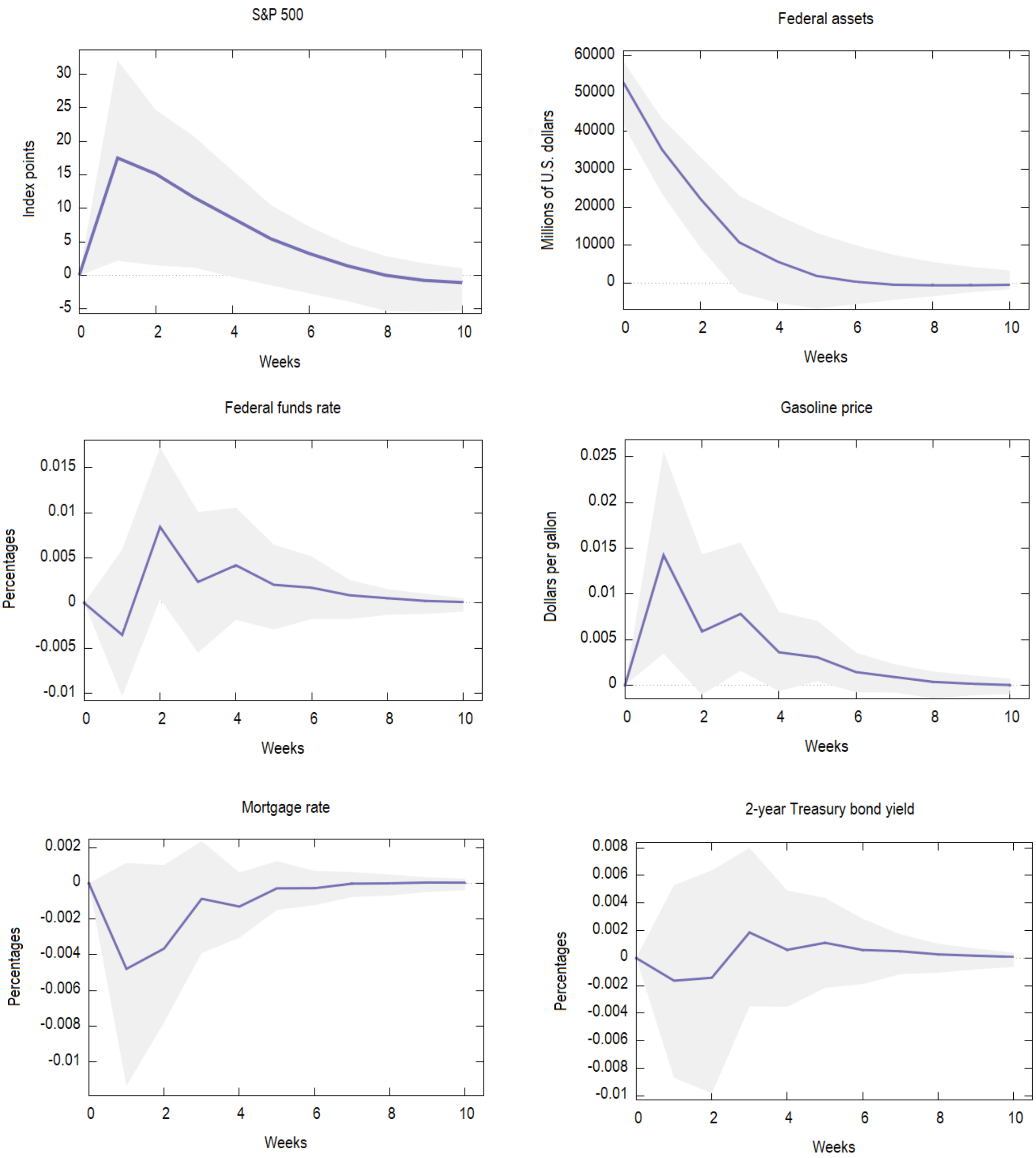
Source: Author’s calculations on the model provided in Appendix 6

Appendix 7. VAR inverse roots in relation to the unit circle



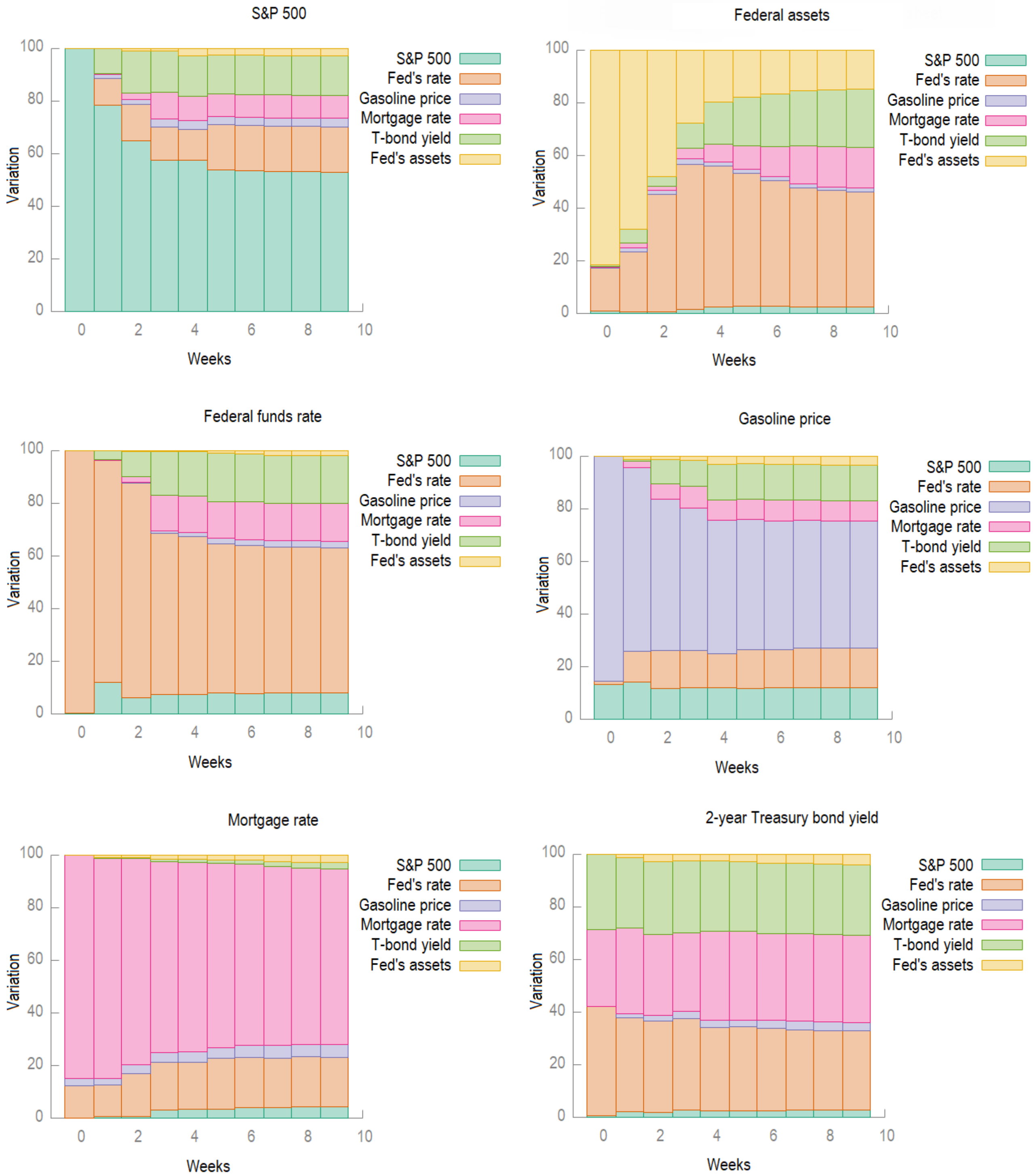
Source: Figure created by the author in Gretl on the model provided in Appendix 6

Appendix 8. IRF graphs



Source: Figures created by the author in Gretl on the model provided in Appendix 6

Appendix 9. FEVD graphs



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