STOCK MARKET EFFECTS OF UNCONVENTIONAL MONETARY POLICY

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ABSTRACT

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Abstract

While the existing academic literature has demonstrated the positive effects of unconventional monetary policy on the real economy and financial markets, its primary focus has been on the early post-global financial crisis period. This thesis aims to contribute to the literature by using more recent data sample from 2004 to 2021, including also the COVID-19 period. In this thesis, I examine the effects of unconventional monetary policy on stock market valuations and the real economy. To account for the dynamic relationship between rare disaster risk and unconventional monetary policy, an important factor highlighted in previous literature, I incorporate rare disaster risk proxied by implied volatility into the analysis. I use the structural VAR model with sign restrictions to uncover the dynamic causal relationships between the variables.

The results indicate that an exogenous unconventional monetary policy shock has a positive and persistent effect on stock market valuations in the euro area and in the US, as well as a positive and persistent effect on the ex-ante growth rate in the euro area and a positive and transient effect in the US. Furthermore, an exogenous implied volatility shock leads to a negative and persistent effect on stock market valuation and ex-ante growth in both regions. Importantly, the findings suggest that the central banks should refrain from adjusting their monetary policy in response to a negative shock to stock market valuations.

Key words
Unconventional monetary policy, rare disaster risk, stock market, structural vector autoregressive model

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1 INTRODUCTION

1.1 Motivation

The global COVID-19 pandemic in early 2020 led to a sharp decline in real economic activity and prompted extensive quantitative easing measures by the world's two largest central banks. In the euro area, the industrial production index plummeted by 14.7 %, while in the US, it dropped by 8.1 %. From the beginning of 2020 until the end of 2021, the European Central Bank (ECB) increased its balance sheet assets by €3.9 trillion and the Federal Reserve (Fed) by $4.6 trillion.

However, these large central bank balance sheet extensions did not occur in isolation. In the euro area (Figure 1) and the US (Figure 2), the increases in the central bank balance sheet assets were preceded by spikes in implied volatility indexes.

These spikes in the implied volatility indexes could be interpreted as reflecting an increase in "rare disaster fears" as titled by Junttila & Martin (2021). The idea of rare disaster fears or rare disaster risk and its effects on the economy are based on the literature developed primarily by Rietz (1988) and Barro (2006, 2009, 2022) with contributions from Wachter (2013), Welch (2016) and Cochrane (2017). The literature on rare disaster risk examines how potential rare disasters in the economy can help to explain the asset-pricing puzzles observed in economic literature.

While there is a vast academic literature exploring the impacts of unconventional monetary policy on the macroeconomy and financial markets, it is primarily focused on the early period of unconventional monetary policy after the global financial crisis and could now be considered to some extent dated. The more recent literature has focused on the unconventional monetary policy and its effects on the macroeconomy (Mouabbi & Sahuc, 2019), bank lending and security holdings (Paludkiewicz, 2021), market liquidity (Christensen & Gillan, 2022), and on the persistence of these effects (Hesse et al., 2018; Neely, 2022).

This thesis aims to contribute to the existing academic literature by incorporating rare disaster risk into the model with fresh data. The data sample used in this thesis covers the COVID-19 period, which has not been utilized in previous literature exploring the connections between the macroeconomy, financial markets, unconventional monetary policy, and rare disaster risk (Boeckx et al., 2014; Kremer, 2016). Furthermore, this thesis utilizes model specifications differing from previous literature.

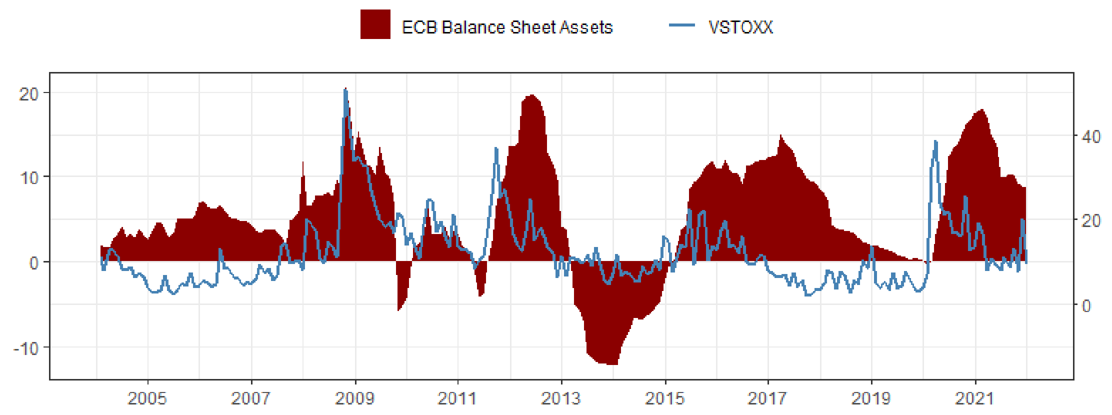

Figure 1 The relationship between ECB balance sheet asset growth (left axis) and VSTOXX (right axis). Sources: Federal Reserve Economic Data (FRED) and Qontiqo.

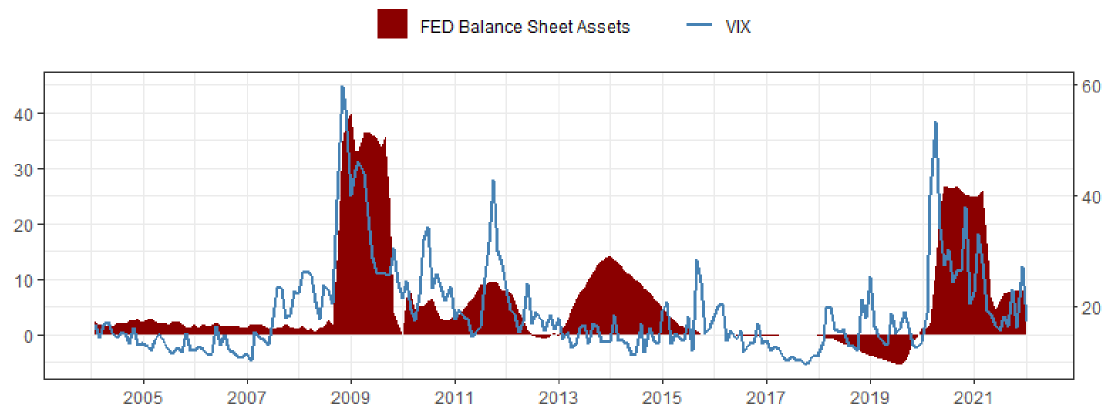

Figure 2 The relationship between Fed balance sheet asset growth (left axis) and VIX (right axis). Sources: FRED and CBOE.

In this thesis, I use both a standard vector autoregressive (VAR) model, first proposed by Sims (1980) and a structural VAR model with sign restriction which follows the approach proposed by Uhlig (2005).

I find that an exogenous unconventional monetary policy shock has a positive and persistent effect on stock market valuations in the euro area and in the US. Additionally, the effects of policy shock on the ex-ante growth rate are positive and persistent for the euro area, and positive and transient for the US. I also find that an exogenous implied volatility shock has a negative and persistent effect on stock market valuation and the ex-ante growth in both regions. In addition, I find that the central banks should refrain from adjusting their monetary policy in response to a negative shock to stock market valuations.

Based on the results presented in this thesis three general policy recommendations can be made. First, when facing a negative stock market valuation shock the central bank should refrain from implementing an easing monetary policy. This is because generally in light of this result in this thesis, the easing policies might not necessarily lead to the outcomes desired when implementing them, but they may actually exacerbate the negative effects.

Second, an exogenous monetary policy shock is likely to have a positive and persistent effect on the economy, and the central banks may consider implementing them in order to stimulate the real economy. Finally, when the central bank identifies an increase in the rare disaster risk, it should take appropriate measures to mitigate the potential negative effects that this risk may have on the economy.

1.2 Research questions

This master's thesis examines the effects of unconventional monetary policy on stock market valuations. The thesis does this by studying the dynamic relationships between stock markets, unconventional monetary policy actions, implied volatility, and the real economy. The main research question could be stated as:

How are the stock market valuations affected by different shocks in the economy?

The main research question could be further narrowed to examine:

1. *How are the stock market valuations affected by exogenous unconventional monetary policy shock?*
2. *How are the stock market valuations affected by exogenous implied volatility shock?*
3. *How are the stock market valuations affected by the initial negative shock to itself?*

These questions are studied for the euro area and the United States (US), and differences between the results are examined.

1.3 Research methods

The data used in this thesis is collected from REFINITIV/Datastream and public databases such as Federal Reserve Economic Database (FRED). The relationships between the chosen variables are studied using a standard vector autoregressive (VAR) model and a structural VAR model with sign restrictions.

The empirical methodology used for the sign restricted structural VAR model follows the study of Uhlig (2005) which is a rejection method.

1.4 Structure of the thesis

This thesis is structured as follows. Sections 2 and 3 present the relevant theoretical framework and literature respectively. Section 4 introduces the data and methodology used in this thesis. Section 5 presents the empirical results of this thesis and discusses the results. Section 6 concludes.

2 THEORETICAL FRAMEWORK

2.1 Asset price channels of unconventional monetary policy

Following the global financial crisis, the zero-lower-bound problem emerged. The conventional monetary policy tools were made ineffective as the key interest rates in the euro area and the US were forced down to essentially zero. As a result, central banks introduced new unconventional monetary policy measures to stimulate the economy.

The effective zero-lower bound created a disconnection between the key interest rates and market rates (Joyce et al., 2012). Consequently, interest rate policies were largely replaced by various balance sheet policies (Joyce et al., 2012; Gambacorta et al., 2014), including asset purchase programs (APPs) by the ECB and large-scale asset purchases (LSAPs) by the Fed.

The ECB's APPs consisted of multiple individually tailored programs targeting different sectors of the economy (European Central Bank, 2022). LSAPs on the other hand were quantitative easing programs carried out by the Fed between 2008 and 2014 (Federal Reserve Bank, 2018). As illustrated in Figure 3, the balance sheets of the ECB and the Fed grew significantly as a result of these policies.

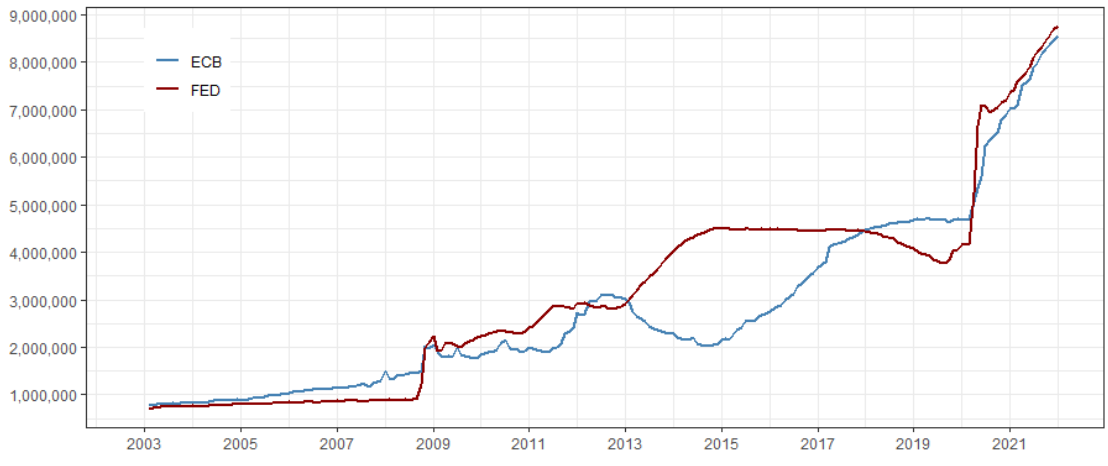

Figure 3 Central bank balance sheet assets for the Federal Reserve and the European Central Bank. Source: FRED.

Unconventional monetary policy affects asset prices through multiple channels. The key channels can be divided into portfolio balance channel, liquidity channel, credit channel, risk-taking channel, signaling channel, and confidence channel.

The portfolio balance channel affects the asset prices through the relative change in asset yields (Joyce et al., 2017). When the central bank purchases a financial asset, it increases its price and decreases the yield of the asset. This prompts the investors from whom the central bank bought the asset, to seek out an alternative riskier investment to maintain their expected return. (Joyce et al., 2017.) Therefore, this would indicate increased demand for the alternative asset and an increase in that asset's price.

The liquidity channel, on the other hand, affects asset prices through the associated liquidity premium (Christensen & Gillan, 2022). The presence of central banks in the asset markets can decrease the liquidity premium (Duffie et al., 2007), which in turn affects the asset prices. This, however, applies only to the markets that the central banks participate in (Christensen & Gillan, 2022).

Unconventional monetary policy can also affect asset prices through the credit channel, which refers to the effects of interest rate changes on asset prices (Warner & Georges, 2001). Easing monetary policy changes have an impact on stock prices through firms' financing conditions, and monetary policy changes should have a relatively larger impact on stock prices of firms with more leverage (Warner & Georges, 2001). During the zero-lower-bound era when the central banks have been unable to affect the interest directly they have included corporate bond purchases in the quantitative easing programs (European Central Bank, 2022). Therefore, the quantitative easing programs have eased the credit market conditions for the firm sector.

The risk-taking channel initially coined by Borio & Zhu (2012) introduces the link between monetary policy and the risk perception of individuals which also affects the pricing of risks. The risk-taking channel is close to the liquidity and portfolio balance channels, and it can be considered as an additional multiplier to these channels. As the central bank increases liquidity through quantitative easing, individuals shift their portfolios toward riskier alternatives. The risk-taking channel adds a dimension to this as Borio & Zhu (2012) argue that the easing monetary policy also decreases the risk perceptions of individuals. They also argue that the risk-taking channel provides a key mechanism for the transmission of monetary policy which should be accounted for by the central bank reaction function (Borio & Zhu, 2012).

The signaling channel refers to the monetary policy's ability to lower the expectations of future short-term interest rates, thereby decreasing the long-term interest at the current period (Weale & Wieladek, 2016). According to Zhang (2022), the monetary policy actions by the central bank reflect the private information of the central bank. After a policy announcement, investors update their beliefs and preferences based on the information (Zhang, 2022). Bernanke (2020) suggests that quantitative easing signals commitment by the central bank to keep the short-term interest rates low in the future. This is partly because the quantitative easing programs announce their length and the central banks have not ended them before the indicated end (Bernanke, 2020).

Recent literature suggests strong signaling effects of unconventional monetary policy (eg. Bauer & Rudebusch, 2013; Bauer & Neely, 2014). The signaling effects also coexist with the portfolio rebalancing effects (Bauer & Neely, 2014). Bauer & Rudebusch (2013) suggests statistically and economically significant signaling effects in the US. Bauer & Neely (2014) indicate that the signaling effects have been stronger for the US whereas moderate for Germany. They suggest, however, that portfolio rebalancing effects have been more substantial in Germany than in the US (Bauer & Neely, 2014), possibly due to the different quantitative easing policy structures in the US and Europe.

The confidence channel affects asset prices through consumer and investor confidence (Hesse et al., 2018). The impact of the confidence channel can be quantified through the consumption capital asset pricing model (CCAPM). Expected excess returns in CCAPM can be shown to be dependent on the covariance between future consumption growth and future realized excess returns, so

$$E(R^e_{t+1}) = \gamma cov(\Delta c_{t+1}, R^e_{t+1}) \quad (1)$$

where R^e_{t+1} is excess return, γ is the coefficient of risk aversion, and Δc_{t+1} denotes the consumption growth (Cochrane, 2017). As stated by Cochrane (2017), equation (1) is able to capture fear-inducing features of recessions which lower consumption. If consumer confidence is low, consumers expect lower future consumption which causes the required excess return by consumers to be higher to justify them transferring their consumption to the future.

Karnizova & Khan (2015) suggest that there is a relationship between stock prices, volatility changes, and consumer confidence. An increase in stock market volatility decreases consumer confidence (Karnizova & Khan, 2015), resulting in consumers demanding higher expected returns to justify delaying consumption, which in turn decreases their total utility. Hesse et al. (2018) indicate that the quantitative easing programs generally should have a positive effect on consumer confidence. Therefore, unconventional monetary policy should decrease stock market volatility, as consumers are more willing to delay their consumption after unconventional monetary policy shocks.

All six channels introduced contribute to the understanding of the transmission of unconventional monetary policy to the asset markets. However, as noted by Hesse et al. (2018), the effects of these channels are heterogeneous across periods. They find that the impact of unconventional monetary policy actions has decreased, likely due to better anticipation of the effects of monetary policy (Hesse et al., 2018). Therefore, this would suggest that the asset prices may be less affected by the more recent unconventional monetary policy actions.

2.2 Implied volatility and disaster risk

The disaster risk literature suggests that the rare disasters can account for a significant part of the observed equity premia in financial markets (Barro, 2006, 2009). Moreover, Barro (2006) notes that rare disaster risks can explain other financial puzzles, such as low risk-free rates, low expected real interest rates, and high stock return volatility.

To address the equity premium puzzles, Barro (2006, 2009, 2022) developed a representation of the economy based on Lucas's (1978) fruit-tree model. In this framework, the economy can be compared to a fruit-tree, where new branches grow over time, but some branches are permanently destroyed. In other words, the overall productivity of the economy increases but there are occasional productivity losses, which could be characterized as economic downturns. In the fruit-tree model, the real economy productivity follows a random walk process with a drift which can be represented as

$$\log(A_{t+1}) = \log(A_t) + c + u_{t+1} + v_{t+1} \tag{2}$$

where A is productivity and c is the drift term. u_{t+1} represents the random walk term with zero mean and v_{t+1} captures the rare disaster risks with the mean of $E(1-d)$. d is the proportional contraction of output in the economy. (Barro, 2006.)

Barro (2009) expanded the framework by modifying the formation of preferences in the model. The utility function used in Barro (2006) assumes that the coefficient for risk aversion (γ) and the reciprocal of the intertemporal elasticity of substitution ($1/\theta$) are equal, or in other words $\gamma = \theta$. Barro (2009) introduces a preference set similar to Epstein & Zin (1989) and Weil (1990) allowing $\gamma \neq \theta$ and enabling a broader set of equity puzzles to be explained. Barro (2022) offers the most recent version of his framework. In addition to Barro (2009), the most recent version allows for endogenous growth and saving.

In Barro (2022) consumption is given as

$$C_t = Y_t - I_t = AK_t - sK_t \tag{3}$$

where C_t is consumption, I_t is investment, A is productivity, K_t is the capital stock, and t denotes the period. Savings rate s is given as

$$s = \delta + \frac{1}{\theta}\left\{A - \delta - \rho - \gamma\sigma^2\left[1 + \frac{1}{2}(\gamma - \theta)\right] - p\left(\frac{1-\theta}{\gamma - 1}\right)\left[E(1-d)^{1-\gamma} - 1\right]\right\} \tag{4}$$

where δ is the depreciation rate, ρ represents time-preferences of investors, p is the probability of rare disaster, and d is the size of the rare disaster (Barro, 2022).

Equation (3) can be rearranged as

$$A - s = \frac{C_t}{K_t} = \frac{C_t}{V_t} \tag{5}$$

where K_t can be substituted to V_t, the value of equity, as in the framework of Barro (2022) giving us dividend yield on the right-hand side of the equation as a linear combination of productivity and the savings rate.

Dividend yield can be also derived through the expected return on equity and the expected growth rate of the real economy. Barro (2022) derives the expected growth rate as

$$E(g_t) = s - \delta - p * E(d) \tag{6}$$

and the expected return on equity as

$$E(r_t^e) = A - \delta - p * E(d) \tag{7}$$

Subtracting equation (6) from equation (7) yields the common discount factor used for example in the Gordon growth formula

$$E(r_t^e) - E(g_t) = A - s \tag{8}$$

Changes in dividend yield are typically caused by fluctuations in asset prices, rather than changes in the dividends themselves. This is because dividends tend to be less volatile than asset prices (Shiller, 1981.) According to the Gordon growth formula, stock prices must reflect changes in the discounting factor, not dividends. Consequently, an increase in the discount factor will result in an increase in the dividend yield, while a decrease in the discount factor will result in a decrease in the dividend yield.

However, one limitation of Barro's framework for the present thesis is that it derives a long-term model that may not be suitable for short-term analysis. For the purposes of this thesis time-variation in the relationships between the key variables needs to be introduced.

Time-variation can be introduced to the system through time-varying productivity or savings rate. This could be done, for example, through time-varying preferences or risk aversion. However, the present thesis is interested in the relationship between rare disaster risk and financial and macroeconomic variables. Therefore, time-variation needs to be introduced through the time-varying probability or the size of rare disasters, with a focus in this thesis on the former as it is easier to proxy. The importance of allowing the probability of rare disasters to vary has been previously discussed in the literature by for example Wachter (2013) and Welch (2016).

Wachter (2013) argues that allowing the probability of rare disasters to vary can better explain the high equity premium and high volatility of stock prices, without having high risk aversion coefficients. This finding is important for the present thesis as it focuses on the relationship between rare disaster risk and financial and macroeconomic variables.

In his paper Barro (2022) proposes the following representation when deriving the gross savings rate.

$$\left[\frac{A-s_{t+1}}{A-s_t}\right]^{\gamma} - 1 \approx -\theta s_t \Big\{-\rho + A - \delta(1-\theta) - p * E(d) * (\gamma - \theta - 1) - \gamma\sigma^2 * \left[1 + \tfrac{1}{2}(\gamma - \theta)\right] - p * \left(\tfrac{1-\theta}{\gamma-1}\right) * [E(1-d)^{-\gamma} - 1]\Big\} \quad (9)$$

The first derivative of the right-hand side terms of equation (9) with respect to the probability of rare disasters gives us

$$E(d) * (\gamma - \theta - 1) - \left(\frac{1-\theta}{\gamma - 1}\right) * [E(1-d)^{-\gamma} - 1] > 0 \quad (10)$$

where the increase in rare disaster risk increases the discount rate when using the parameter values defined by Barro (2022). For the different parameters, Barro (2022) proposes values of $\gamma = 4$, $\theta = 0.5$, $E(d) = 0.21$, and $E(1-d)^{-\gamma} = 4.0$.

Therefore, an increase in the probability of rare disasters leads to an increase in consumption, as shown in equation (3). A similar effect is also proposed by Wachter (2013), who suggests that when the probability of disaster increases the conditional distribution of consumption growth becomes highly nonnormal. Also, with a positive shock to the probability of rare disasters, the dividend yield should increase according to equation (5).

Barro (2022) also provides the derivation for the risk-free rate in the system

$$r_f = A - \delta - \gamma\sigma^2 - p * E[d * (1-d)]^{-\gamma} \quad (11)$$

where the $E[d * (1-d)]^{-\gamma}$ term is equal 1.7. Therefore, a 1 % increase in the probability of rare disasters results in a 1.7 % decrease in the risk-free rate in the model which is a rather large change. Therefore, when the probability of rare disasters increases, the central bank generally should respond by easing monetary policy.

To understand the relationship between disaster risk, expected growth rate, and dividend yield, it is important to proxy the rare disaster risk. To proxy the rare disaster risk, previous literature has suggested using economic uncertainty measures such as Composite Indicator of Systematic Risk (CISS) (Boeckx et al., 2014; Kremer, 2016), economic policy uncertainty (Baker et al., 2016), and the price of volatile stock indicator defined by the difference between the book-to-market ratio of high and low volatility stocks (Pflueger et al., 2020). Kremer (2016) proposes that the CISS indicator is an important factor in determining the future development of output growth, monetary policy rates, and inflation. There is also strong co-movement between ECB balance sheet assets and the CISS indicator (Boeckx et al., 2014; Kremer, 2016). Additionally, some researchers have used implied volatility indexes as proxies for the rare disaster risk, such as Gambacorta et al. (2014) and Junttila & Martin (2021).

This thesis uses implied volatility indexes to proxy the rare disaster risk, specifically the Chicago Board Options Exchange Volatility index (VIX) and EURO STOXX 50 Volatility index (VSTOXX). Figure 1 and Figure 2 show the co-movement between the respective development of central bank balance sheet assets and the implied volatility index for the euro area and the US. After the global financial crisis, the shocks in implied volatility seem to cause a lagged positive reaction in the central bank balance sheet asset growth.

The figures highlight one significant difference between the conduct of monetary policy between the ECB and the Fed. The Fed seems to react more strongly to the increase in implied volatility, but their balance sheet extensions continue for a shorter period compared to ECB.

2.3 Monetary policy and macroeconomy

In the previous section, we discussed the importance of allowing the probability of rare disasters to vary across time. While Barro's framework provides us with a way to understand the relationships between rare disaster risk, monetary policy, the macroeconomy, and stock prices, the framework of Boehl (2022) offers a more comprehensive understanding of these dynamic relationships.

Boehl (2022) provides a general equilibrium system to link the previous section to the macroeconomy, and derives the following set of equations

$$\pi_t = \beta E_t \pi_{t+1} - \kappa x_t \tag{12}$$

$$y_t = E_t y_{t+1} - (r_{t+1} - E_t \pi_{t+1}) + d_t \tag{13}$$

$$x_t = \nu s_t - \psi y_t - (r_{t+1} - E_t \pi_{t+1}) + \frac{1+\eta}{1+\bar{\nu}} a_t \tag{14}$$

$$r_{t+1} = \varphi_\pi \pi_t + \varphi_y \hat{y}_t + \varphi_s s_t \tag{15}$$

$$s_t = \beta \hat{E}_t s_{t+1} - (r_{t+1} - E_t \pi_{t+1}) \tag{16}$$

where equation (12) is the New Keynesian Phillips curve where π is inflation, x is a markup over wholesale prices, β is the quarterly household discount rate, and κ is the slope of the Phillips curve. Equation (13) describes the dynamic IS curve where y is the output in the economy, r is the nominal interest rate, and d is the aggregate preference shock. Equation (14) describes the transmission channel of asset prices to the economy where s denotes the asset prices, υ is the elasticity of markup to asset prices, ψ is the elasticity of markup to output, η is the disutility of labor, and a is productivity. Equation (15) is the linearized monetary policy rule employed by the central bank where φ is the policy parameter and $\hat{y}$ is the output gap. The output gap is defined as $y_t - y_t^{f,RE}$ where the latter term is the output under flexible prices and rational expectations. Finally, equation (16) describes the asset price development in the system. (Boehl, 2022.) In the linearized monetary policy rule, the central bank's response to a shock depends on the size of the monetary policy parameter (φ). The central bank responds to shocks in inflation, output gap, and asset prices.

In the Boehl (2022) framework, change in rare disaster risk can be assessed endogenously or exogenously. An exogenous shock to rare disaster risk can be assessed through equation (10) and equations (12) – (16). A positive shock to rare disaster risk increases the discount factor of stocks in equation (10) which leads to a decrease in stock prices. The decrease in stock prices results in a decrease in markup described by equation (14) causing an increase in inflation in equation (12). If the central bank follows the Taylor principle and raises the nominal interest rate more than one-to-one to inflation, it leads to a decrease in aggregate demand and subsequently a decrease in output. Additionally, an increase in the real interest rate causes asset prices to further decrease if the real interest rate increases.

Alternatively, the rare disaster risk shock could be assumed to affect the system endogenously. In this case, the shock affects the system through the aggregate preference shock d_t in equation (13). Karnizova & Khan (2015) argue that an increase in stock market volatility results in a decrease in consumer confidence, which can be interpreted as affecting consumer preferences in this context. Thus, a positive shock to rare disaster risk, as measured by stock market volatility, increases consumption in the current period and subsequently raises inflation. This leads to an increase in the nominal interest rate by the central bank thereby causing a similar reaction to that observed in exogenous rare disaster risk shock. The frameworks of Barro (2022) and Boehl (2022) provide similar conclusions regarding the relationship between unconventional monetary policy and the other variables, as the asset price channels discussed earlier. The impact of the confidence channel is especially highlighted through the rare disaster risk, which influences growth rate and real interest rate expectations as well as stock prices.

The frameworks of Barro (2022) and Boehl (2022) draw similar conclusions regarding the relationship between unconventional monetary policy and the other variables, as the asset price channels discussed earlier. The impact of the confidence channel is especially highlighted through the rare disaster risk, which influences growth rate and real interest rate expectations as well as stock prices.

These frameworks provide a comprehensive understanding of the unconventional monetary policy effects on stock market valuations. These frameworks allow us to identify the key variables that may affect stock market valuations in the unconventional monetary policy era. These variables include output, nominal interest rate, inflation, markup, and stock prices, although nominal interest rate and inflation typically affect the system together as the real interest rate. However, for the purposes of this thesis, markup will not be included due to difficulties in obtaining reliable data. Additionally, previous literature related to this thesis has not included markup in their analysis. Also, as discussed in the previous section, a proxy of the probability of rare disaster risk needs to be included in the system.

The zero-lower-bound problem during the last decade presents a significant challenge for the Boehl (2022) framework. With the nominal interest rates close to zero the central bank used quantitative easing and forward guidance as their main monetary policy tools (Bernanke, 2020). Therefore, the linearized monetary policy rule in equation (15) alone is an insufficient measure of monetary policy during the zero-lower-bound era (Gambacorta et al., 2014). Therefore, in addition to the real interest rate, a measure of unconventional monetary policy must be included in the analysis.

Previous literature has suggested two main measures of unconventional monetary policy, i.e., the shadow rate proposed by Wu & Xia (2016) and the central bank balance sheet assets proposed by Gambacorta et al. (2014). Wu & Xia (2016) find that the shadow federal funds rate exhibits a similar correlation to the macroeconomy as the actual federal funds rate prior to the global financial crisis. One key weakness of the shadow rate, however, is that its values are dependent on the model used to calculate it (Wu & Xia, 2016). Therefore, the central bank balance sheet assets could be seen as a more robust measure of unconventional monetary policy as it does not depend on the model used. Gambacorta et al. (2014) also note that the central bank balance sheet has been the main monetary policy tool in the zero-lower-bound era.

3 LITERATURE REVIEW

Following the global financial crisis, the effectiveness of conventional monetary policy was constrained by the effective lower bound on short-term interest rates (Bernanke, 2020). Central banks responded by augmenting their monetary policy toolkits with unconventional monetary policy tools, primarily quantitative easing and forward guidance (Bernanke, 2020). The resulting quantitative easing programs led to an unprecedented increase in the central bank balance sheet assets, as highlighted in Figure 3.

The previous literature indicates a general consensus that unconventional monetary policy has a positive effect on the macroeconomy (see e.g. Gambacorta et al., 2014; Hesse et al., 2018; Mouabbi & Sahuc, 2019). Specifically, unconventional monetary policy actions aim to stimulate real economic activity and inflation by lowering the long-term yields and thus supporting borrowing by businesses and households (Baumeister & Benati, 2013).

The estimated size of the unconventional monetary policy effects varies between studies and different countries and regions. For instance, Kapetanios et al. (2012) found that the Bank of England's first quantitative easing program had a maximum positive effect of 1.5 % on GDP growth and 1.25 percentage points on CPI inflation respectively. On the other hand, Baumeister & Benati (2013) estimate that quantitative easing had approximately a 2 % positive effect on both GDP growth and inflation. For the US, Baumeister & Benati (2013) found a smaller but still positive effect on growth and inflation.

Gambacorta et al. (2014) present different results concerning the relative size of growth and inflation responses to unconventional monetary policy shocks. Consistent with previous studies by Kapetanios et al. (2012) and Baumeister & Benati (2013) they find a positive effect on growth and inflation. However, in contrast to previous findings, they report that the response of growth is approximately three times larger than the response of inflation at its peak to unconventional monetary policy shock. Additionally, the growth and inflation responses and their persistency vary across countries (Gambacorta et al., 2014).

The early quantitative easing programs have also been found to have an effect on unemployment. Baumeister & Benati (2013) estimated that without quantitative easing, unemployment in the US would have been approximately 0.5 percentage points higher than what was observed. Similarly, Wu & Xia (2016) found that unconventional monetary policies were able to lower the unemployment rate in the US by 1 percentage point.

More recent studies have produced similar results regarding the effects on growth and inflation. Weale & Wieladek (2016) found that a quantitative easing shock of 1 % of GDP resulted in a 0.58 % increase in real GDP and a 0.62 % increase in CPI inflation. Additionally, Mouabbi & Sahuc (2019) found that without unconventional monetary policy, yearly GDP growth and inflation would have been 1.09 % and 0.61 % lower, respectively, between 2014 and 2017.

In summary, previous literature indicates the macroeconomic effects of unconventional monetary policy are generally larger in the US compared to the euro area (e.g. Gambacorta et al., 2014; Papadamou et al., 2019), and the effects on GDP growth are typically 1.5 to 3 times larger than those on inflation (Gambacorta et al., 2014).

Finally, the effects of unconventional monetary policy on the macroeconomy seem to have decreased. Hesse et al. (2018) indicate that the scale of the effects of quantitative easing shocks has decreased after the early quantitative easing programs. Also, the statistical significance of the effects is stronger for the early quantitative easing programs (Hesse et al., 2018). This may be due to the better anticipation of the quantitative easing programs and their effects on the macroeconomy (Hesse et al., 2018).

Unconventional monetary policies have been effective in reducing long-term interest rates and bond yields (Joyce et al., 2012; Rogers et al., 2014). Rogers et al. (2014) find that a significant portion of the yield decreases are due to the decrease in risk premia. Eser & Schwaab (2016) find that the bond yields and volatility are lower for most countries on intervention days with lower volatility stemming from a reduction in tail risk. Eser & Schwaab (2016) suggest that this effect persists in both the short-term and the long-term. Nguyen et al. (2020) have reported similar findings, with the dynamics of liquidity and volatility changing significantly in the US treasury markets just before and after economic announcements.

The yield declines on government bonds as a result of unconventional monetary policy have caused portfolio-balance effects. Joyce et al. (2017) indicate that institutional investors have shifted their holding from government bonds to corporate bonds due to quantitative easing. Similarly, Paludkiewicz (2021) indicates that banks shifted their holdings away from government bonds after yield declines. This therefore would also indicate that the corporate bond yields have decreased as a result of increased demand.

Unconventional monetary policy and quantitative easing can also impact market liquidity (Christensen & Gillan, 2022). Christensen & Gillan (2022) found that the liquidity premium in the markets decreased by approximately ten basis points during the Fed’s quantitative easing program targeting Treasury Inflation-Protected Securities (TIPS). They also suggest that the effects of increased liquidity are the largest for more illiquid securities (Christensen & Gillan, 2022).

Unconventional monetary policies have been found to positively impact stock markets in Europe (Haitsma et al., 2016). Similarly, Swanson (2021) suggests that a one standard deviation quantitative easing shock can increase US stock prices by 0.1 %. Haitsma et al. (2016) also found strong support for an existing credit channel in the unconventional monetary policy period. Stocks of high-leverage firms’ showed a stronger reaction to the unconventional monetary policy shock compared to low-leverage firms (Haitsma et al., 2016).

The time-varying effects of monetary policy on the economy and asset prices are examined by Paul (2020) and Bianchi et al. (2022). The effects of monetary policy have been heterogenous in the past, particularly in the context of the US (Paul, 2020; Bianchi et al., 2022). Prior to the global financial crisis, the reaction of house and stock prices to monetary policy shock was lower (Paul, 2020) indicating a larger response in the current environment. Bianchi et al. (2022) have also found that monetary policy regimes affect the level of asset prices with expansionary monetary policy regimes characterized by higher asset prices.

Long-standing belief in the literature has been that the effects of unconventional monetary policy shocks are only temporary (eg. Gambacorta et al., 2014). This view is highly influenced by the result of Wright (2012). In his study, he uses a structural VAR model to estimate the effects of unconventional monetary policy shock on long-term interest rates (Wright, 2012). Wright (2012) finds that the unconventional monetary policy shocks have had yield-decreasing effects, but that the effects have been only transient. However, Neely (2022) challenges the view and methodology used by Wright (2012) showing that the results of Wright (2012) are not robust to the specification and data used. In contrast, Neely (2022) indicates persistent effects of unconventional monetary policy shocks. Hesse et al. (2018) propose similar findings to Neely (2022). They indicate that unconventional monetary policy shocks have had a persistent effect on stock prices (Hesse et al., 2018).

Recent literature, including Altavilla & Giannone (2017), Altavilla et al. (2019), and Swanson (2021), increasingly supports the persistent effects of unconventional monetary policy shocks. Altavilla & Giannone (2017) analyze how unconventional monetary policy shocks affect forecasters' expectations of future bond yield. Altavilla et al. (2019) study the effects of policy announcements in Europe on sovereign yields, exchange rates, and stock prices, finding persistent effects on stock prices and long-term interest rates. Swanson (2021) conducted a similar study in the US. He finds that quantitative easing and forward guidance had large effects on treasury and corporate bond yields, as well as on stock prices and exchange rates (Swanson, 2021). Excluding the effects of the Fed's QE1 program, the effects of unconventional monetary policy shock have been persistent in the US (Swanson, 2021).

The question of whether central banks should use leaning against the wind policies when the asset markets show signs of overheating has been extensively discussed in the literature (see e.g. Galí, 2014; Svensson, 2014, 2017; Caines & Winkler, 2021; Boehl, 2022). Leaning against the wind policies could be characterized as a monetary policy which tightens when asset prices exceed their fundamental values and eases when they are below them. Galí (2014) suggests that in the case of a rational asset price bubble, leaning against the wind policies can affect the economy more adversely than if the central bank did not react to the bubble.

Svensson (2014) studied the use of leaning against the wind policies by the central bank in Sweden. Svensson (2014) finds significant costs to the economy in the form of low inflation and high unemployment. In a later study, Svensson (2017) quantified the effects of leaning against the wind policies and argued that the probability of the crises the central bank aims to prevent, should be 5-40 standard deviations higher than previously estimated in the literature in order to justify their use.

Boehl (2022) similarly found that leaning against the wind policies can create spillover effects on the macroeconomy, despite their potential to reduce the asset market volatility and dampen the financial cycle. In general, the adverse effects on the macroeconomy outweigh the dampening effects of the asset markets (Boehl, 2022).

Contradicting evidence to the recent literature is provided by Caines & Winkler (2021), who argue that the optimal policy structure depends on the assumed sources of financial fluctuation (Caines & Winkler, 2021). They show that when non-fundamental asset price fluctuations are caused by subjective extrapolation from previous asset price development, the optimal policy leans against the wind (Caines & Winkler, 2021). Therefore, if the central bank should generally not react to asset price fluctuations, asset prices, and their volatility should not contain information about future monetary policy actions.

The importance of controlling for the relationship between uncertainty and unconventional monetary policy measures has been suggested in the literature (Boeckx et al., 2014; Kremer, 2016). Kumar et al. (2022) show that a positive shock to the VIX has a contractionary and disinflationary effect, as well as decreasing effect on term premiums due to portfolio-balance effects. This suggests that a positive shock in VIX should also see easing monetary policy actions which is also indicated by Kumar et al. (2022).

Altig et al. (2020) indicate that a positive shock to the VIX and other uncertainty measures has a negative effect on industrial production. Industrial production decreases by 12-19 % with an uncertainty shock similar to COVID-19 (Altig et al., 2020). Urom et al. (2021) also indicate a negative relationship between implied volatility indices and real economic activity. Additionally, they indicate for a feedback loop between the volatility indexes and real economic activity (Urom et al., 2021).

Implied volatility indexes and monetary policy stances move together (Bekaert et al., 2013). Bekaert et al. (2013) divided the VIX index to separate risk aversion and economic uncertainty components. They find that an expansionary monetary policy stance lowers the risk aversion component and the effect is lagged and persistent (Bekaert et al., 2013). This suggests that there may be a significant increase in risk-taking in financial markets as a result of unconventional monetary policy. Gambacorta et al. (2014) also find that the VIX decreases following an unconventional monetary policy shock.

Table 1 summarizes the most important literature reviewed in this section. Table 1 also highlights that the previous literature has been dominated by event studies and different VAR methods. The popularity of the VAR models lies in their ability to capture complex dynamics between multiple time series (Stock & Watson, 2001). However, while the standard VAR model can be a powerful tool for describing data and forecasting, it falls short in providing structural inference and policy analysis (Stock & Watson, 2001). This is because structural inference and policy analysis require differencing correlation and causality (Stock & Watson, 2001). To address this, structural VAR models allow distinguishing between correlations and causality (Stock & Watson, 2001) which therefore can explain the popularity of the structural VAR models in the previous literature.

Table 1 Summary of literature

Author(s)	**Research question/ aim**	**Data**	**Methodology**	**Main results**
Joyce, Miles & Scott (2012)	Identify the impacts of quantitative easing and unconventional monetary policy	-	Literature review	Quantitative easing can lower long-term interest rates and yield and has stimulating effect on economy
Wright (2012)	Identify the relationship between monetary policy shocks and long-term interest rates in the zero-lower-bound	Daily, 11/2008-9/2011	SVAR	Monetary policy shock lowers the long-term interest rates, but the effect is transient
Bekaert, Hoerova & Lo Duca (2013)	Identify the dynamic relationships between risk aversion, uncertainty, and monetary policy	Daily, 1/1990-8/2010	SVAR	Easing monetary policy decreases risk aversion and uncertainty
Wachter (2013)	Examine whether the time-varying rare disaster risk can be used to explain aggregate stock market	Quarterly, Q1/1947-Q1/2010	Linear regression	Many features of aggregate stock market can be explained using time-varying disaster risk
Gambacorta, Hoffman & Peersman (2014)	Examine the macroeconomic effects of unconventional monetary policy	Monthly, 1/2008-6/2011	Panel VAR	An exogenous unconventional monetary policy shock causes a temporary increase in economic activity and consumer prices
Rogers, Scotti & Wright (2014)	Examine the effects of unconventional monetary policy on bond yield, asset prices, and exchange rates	Intraday/daily, 1/2000-4/2014	Event-study	Unconventional monetary policy is an effective tool to ease financial conditions at zero-lower-bound

Wu & Xia (2016)	Examine the macroeconomic effects of unconventional monetary policy	Monthly, 1/1990-12/2013	FAVAR	The Fed's unconventional monetary policy functions similarly as conventional policies prior to the global financial crisis
Altavilla & Giannone (2017)	Identify the effect of unconventional monetary policy shocks on forecasters' perceptions	Quarterly, Q1/1996-Q1/2015	Event-study	Unconventional monetary policy shocks lower bond yield expectations of forecasters
Hesse, Hofmann & Weber (2018)	Identify the effect of unconventional monetary policy shocks on economy and their effectiveness across periods	Monthly 11/2008-11/2016	BVAR	Unconventional monetary policy shocks have a positive effect on macroeconomy, but their effectiveness has decreased
Altavilla, Brugnolini, Gürkaynak, Motto & Ragusa (2019)	Study the financial market effects of unconventional monetary policy shock in the euro area	Intraday, 1/2002-9/2018	Event-study	All yield curve variation is captured by unconventional monetary policy factors on announcement days
Mouabbi & Sahuc (2019)	Examine the macroeconomic effects of unconventional monetary policy	Quarterly, Q1/1999-Q2/2017	DSGE	Unconventional monetary policy effectively increased inflation and GDP growth
Paludkiewicz (2021)	Examine the effect of unconventional monetary policy on bank lending and security holdings	Monthly, 1/2013-12/2015	Panel regression, diff-in-diff	Unconventional monetary policy causes banks experiencing large yield declines to increase their real-sector lending
Swanson (2021)	Examine the financial markets effects of the Fed's forward guidance and quantitative easing	Intraday, 7/1991-6/2019	Event-study	Unconventional monetary policy has functioned similar to the conventional monetary policy prior global financial crisis
Christensen & Gillan (2022)	Examine the effects of quantitative easing on market liquidity	Daily, 1/2005-12/2012	Linear regression	Liquidity premium during the Fed's QE2 program was 10 basis points lower than expected
Neely (2022)	Examine the persistency of unconventional monetary policy shock.	Daily, 11/2008-9/2011	SVAR	Unconventional monetary policy shock has had a persistent effect on yields

4 DATA AND METHODOLOGY

4.1 Data

The empirical models are estimated using monthly data from January 2004 to December 2021 for the euro area and the US. The variables used in this thesis are ex-ante growth rate, ex-ante real interest rate, implied volatility growth, central bank balance sheet asset growth, and dividend yield. This thesis builds on previous literature and employs similar variables, with a few distinctions. Growth rate and real interest rate expectations are used, following the theoretical frameworks of Barro (2022) and Boehl (2022). Additionally, stock price variation is measured through dividend yield.

Data on dividend yield (dy) is based on the aggregate price indexes for both regions. Euro area dividend yield is based on EURO STOXX 600 price index and the US dividend yield on S&P500 composite price index, both sourced from REFINITIV/Datastream.

The ex-ante real interest rate (r) is constructed as the differences between the nominal short-term interest rate and the annualized expected inflation rate, based on fully rational expectations. In other words, the ex-ante real interest rate is constructed by subtracting $t + 12$ inflation from the nominal interest rate at time t. The nominal short-term interest rate used for the euro area is the EONIA midrate and the 3-month T-bill rate for the US. The data for nominal short-term interest rates are sourced from ECB's Statistical Data Warehouse and REFINITIV/Datastream respectively. The annualized inflation rate is constructed using yearly log changes on Consumer Price Index (CPI) data. CPI data for both regions is sourced from REFINITIV/Datastream.

The ex-ante growth rate (g) is constructed using monthly industrial production index data. The growth rate is annualized using yearly log changes on the data and the $t + 12$ growth rate is used to measure the ex-ante growth rate at time t, therefore, reflecting fully rational expectations. The industrial production index data is collected from REFINITIV/Datastream. The unconventional monetary policy is measured using central bank balance sheet asset growth (bs) which is constructed as yearly log changes using balance sheet data from the ECB and the FED. The data for the ECB's and the Fed's balance sheet assets are sourced from FRED.

Implied volatility indexes are used to measure financial uncertainty similar to Junttila & Martin (2021). For the euro area, the EURO STOXX 50 volatility index ($VSTOXX$) is used, and the Chicago Board Options Exchange (CBOE) volatility index (VIX) is used for the US. The data for the implied volatility indexes are sourced from Qontiqo and CBOE respectively. I will use the growth of implied volatility indexes constructed as simple log differences from the data between periods.

Table 2 Descriptive statistics

Panel A: Euro area data					
Stat/Var	*g*	*r*	*VSTOXX*	*bs*	*dy*
Mean	0.17	2.91	0.02	5.07	2.92
SD	2.97	1.41	8.47	6.70	0.46
Min	-14.69	-2.58	-22.40	-12.19	1.85
Max	15.06	4.47	39.13	20.62	5.27
ADF	-4.32***	-0.89	-12.49***	-2.16	-3.32***
PP	-3.93***	-0.33	-17.37***	-1.97	-2.93**
KPSS	0.08	2.49***	0.03	0.12	0.25
Panel B: US data					
Stat/Var	*g*	*r*	*VIX*	*bs*	*dy*
Mean	0.17	0.32	0.05	5.47	1.99
SD	2.25	1.50	9.40	8.57	0.31
Min	-8.10	-2.89	-26.68	-5.38	1.55
Max	6.65	4.10	37.03	40.04	3.60
ADF	-3.68***	-1.54	-12.00***	-3.28**	-2.99**
PP	-3.06**	-0.97	-16.97***	-2.15	-2.42
KPSS	0.10	1.00***	0.03	0.20	0.28

Notes: Table presents the descriptive statistics and unit root tests for the euro area and the US variables. *g* denotes the ex-ante growth rate measured as yearly log-change from industrial production index, *r* denotes the ex-ante real interest rate, *VSTOXX* and *VIX* denote the changes in the implied volatility indexes for the euro area and the US respectively, *bs* denotes the central bank balance sheet asset growth as yearly log-change, and *dy* denotes the dividend yield. Statistical significance levels noted as (***) = 0.01, (**) = 0.05, (*) = 0.10.

Figure 1 and Figure 2 plot the relationship between the central bank balance sheet asset growth and implied volatility index for the euro area and the US respectively, whereas dividend yield, the ex-ante growth rate, and the ex-ante real interest are plotted in Figure 4 and Figure 5 for the regions. Descriptive statistics for the variables are given in Table 2.

The statistical properties in terms of mean and standard deviation are similar for both regions. However, there are some significant differences between them in terms of the minimum and maximum values. For the US, the absolute difference between the extreme values is larger for the central bank balance sheet asset growth, whereas it is larger for the ex-ante growth rate and dividend yield in the euro area.

Due to the construction of the ex-ante growth rate both extreme values for it are observed prior to the COVID-19 crisis as shown in Figure 4 and Figure 5. The same is true for the minimum values for the ex-ante real interest rate. Figure 1 and Figure 2 on the other hand show that for the implied volatility indexes and the central bank balance sheet asset growth the second-highest values for both regions are observed during COVID-19.

Unit root tests are performed using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests with the null hypothesis of a unit root in the time series, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with the null of stationary time series.

All unit root tests indicate stationary time series for the ex-ante growth rate and changes in the implied volatility index for both the euro area and the US whereas unit root in the time series for the real interest rate for both the euro area and the US. However, there are differences for the regions as for the central bank balance sheet asset growth and the dividend yield. All unit root tests indicate stationary dividend yield for the euro area whereas ADF and KPSS tests indicate stationary series for the US. The unit root tests for the central bank balance sheet asset growth offer somewhat contradicting results. For the euro area, ADF and PP tests indicate unit root in the time series, but the KPSS test indicates stationary time series. For the US, ADF and KPSS tests indicate stationary series, and the PP test indicates unit root. For the analysis, all the variables except the ex-ante real interest rate are treated as stationary and the ex-ante real interest rate is differenced.

Table 3 Correlation coefficients

Panel A: Euro area data					
	g	*r*	*VSTOXX*	*bs*	*dy*
g	1.0000				
r	-0.4182***	1.0000			
VSTOXX	-0.1178	0.0893	1.0000		
bs	-0.0502	-0.0326	-0.0603	1.0000	
dy	-0.2437***	0.2222***	0.0577	0.2333***	1.0000
Panel B: US data					
	g	*r*	*VIX*	*bs*	*dy*
g	1.0000				
r	-0.4323***	1.0000			
VIX	-0.1392**	0.1078	1.0000		
bs	0.3186***	-0.4273***	-0.0619	1.0000	
dy	-0.0442	-0.2630***	-0.0417	0.6168***	1.0000

Notes: Table presents the Pearson correlation coefficient. Statistical significance levels noted as (***) = 0.01, (**) = 0.05, (*) = 0.10. See variable definitions from Table 2.

The correlation coefficients are presented in Table 3. A couple of interesting observations arise from the table. First, the correlations between the ex-ante growth rate, central bank balance sheet asset growth, and dividend yield differ between the regions. For the euro area dividend yield and the ex-ante growth rate are correlated whereas not for the US. On the other hand, the ex-ante growth rate and central bank balance sheet asset growth are correlated for the US but not for the euro area.

Second, for the euro area, the ex-ante real interest rate does not seem to be correlated with implied volatility and central bank balance sheet asset growth whereas they are for the US. Finally implied volatility, central bank balance sheet asset growth, and dividend yield are all highly positively correlated with each other for both regions. Also, the ex-ante real interest rate and dividend yield are correlated for both regions, but their signs are different. Various factors could contribute to this difference, for example differing inflation dynamics.

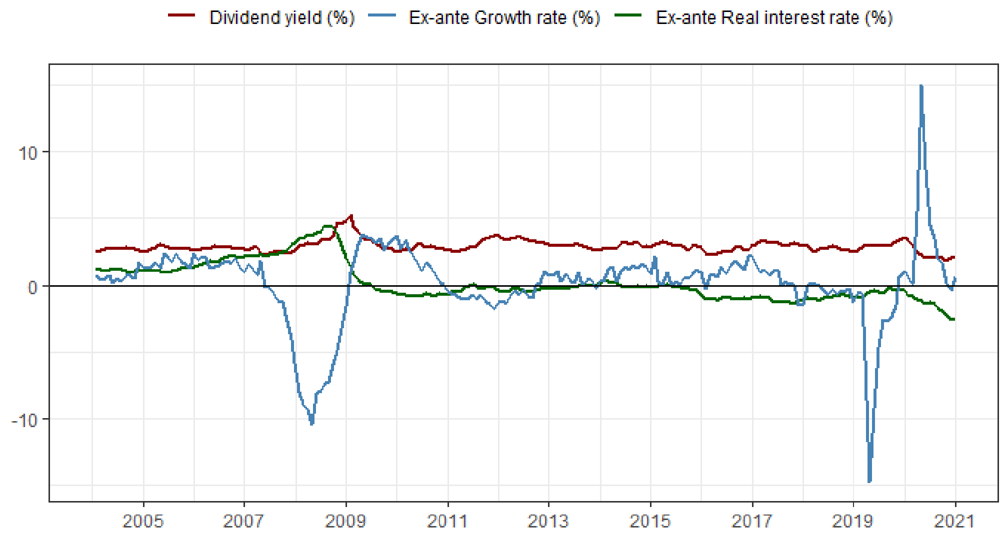

Figure 4 Dividend yield, percentage p.a. growth rate, and percentage p.a. real interest rate for the euro area from January 2004 to December 2021.

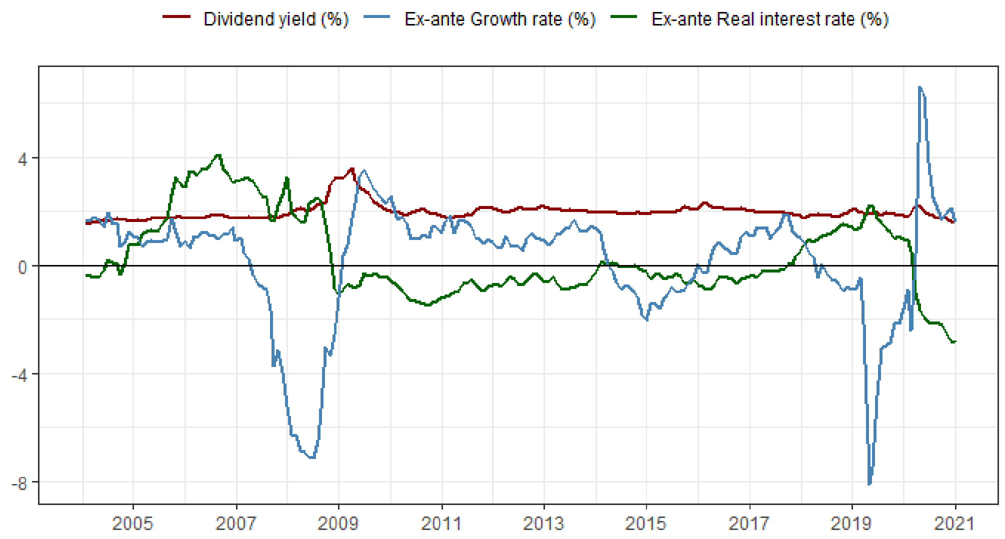

Figure 5 Dividend yield, percentage p.a. growth rate, and percentage p.a. real interest rate for the US from January 2004 to December 2021.

4.2 Methodology

The vector autoregressive (VAR) model is a system of regression equations that was originally popularized by Sims (1980) as a generalization of univariate autoregressive models (Brooks, 2019). A standard form one lag VAR(1) model with n endogenous variables can be given as

$$y_t = Ay_{t-1} + \varepsilon_t \tag{17}$$

where y_t is $n \times 1$ vector of variables, A is $n \times n$ coefficient matrix, and ε is $n \times 1$ vector of one step ahead error terms with zero mean, no autocorrelation, and variance-covariance matrix of Σ (Uhlig, 2005; Fry & Pagan, 2011). The benefit of the standard form VAR model is that it can be estimated using the OLS methodology (Enders, 2015).

VAR models offer several advantages and disadvantages. One advantage of structural vector autoregressive models is their ability to treat all variables as endogenous, offering greater flexibility than standard autoregressive models by allowing variables to be influenced not only by their own lags but also by other variables (Brooks, 2019). However, the standard VAR models are atheoretical by nature, meaning they lack theoretical foundations regarding the relationships of the variables (Brooks, 2019). In addition, VAR models often involve a large number of parameters, which can result in a high degree of freedom and large confidence intervals for parameters (Brooks, 2019).

The number of parameters is greatly dependent on the number of lags in the model. However, choosing the optimal lag length can be difficult as the economic theory often cannot be used to determine it (Brooks, 2019). Different information criteria are typically used to determine the optimal lag length (Brooks, 2019), such as the Akaike information criteria (AIC) (Akaike, 1974) or the Bayesian/Schwarz information criteria (SBIC) (Schwarz, 1978). For the models in this thesis, AIC gives an optimal lag length of 12 lags, while SBIC gives an optimal lag length of 1. In this thesis, a lag length of 12 will be used to allow for the past year to affect the current period. A lag length of 1 would suggest that all the information from the current period is fully incorporated into prices almost instantly which seems unlikely. For instance, monetary policy responses can be sometimes sluggish.

The ordering of variables is a critical aspect in VAR models, as it can impact the impulse responses and variance decompositions (Brooks, 2019). Typically, financial theory is used to identify the variable order (Brooks, 2019). One way to order the variables is to use the approach of Bernanke & Mihov (1998) and order the variables so that “slow-moving” variables are first in order and “fast-moving” variables are last in order (Uhlig, 2017).

For the purpose of this thesis, I will use a similar approach to order the variables so that the order is

$$y_t = [g_t^e, r_t^e, \sigma_t, bs_t, dy_t] \quad (18)$$

The problem with the standard VAR approach is that it is often insufficient in recovering the structural shocks from the data (Uhlig, 2017). Therefore, a structural VAR model with additional restrictions is needed to recover the structural shocks (Uhlig, 2017).

The restrictions in the structural VAR model could be imposed in several different ways. Enders (2015) proposes four different alternatives: coefficient, variance, symmetry, and sign restrictions. To recover the structural shocks in the empirical analysis of the model considered in this thesis, the structural VAR model with sign restrictions, based on the methodology of Uhlig (2005), will be employed.

To be able to recover the structural shocks needed there must be a matrix B so that

$$e_t = B\varepsilon_t \quad (19)$$

where e_t is the error term structural model and ε_t is the error term in the unrestricted model. B can be estimated from the variance-covariance matrix as

$$\Sigma = BB' \quad (20)$$

where B is $n \times n$ coefficient matrix (Uhlig, 2017). Therefore, the structural VAR model also used in this thesis can be given as

$$y_t = Ay_{t-1} + B\varepsilon_t \quad (21)$$

and the resulting impulse response function as

$$r_k = A^k B u_j \quad (22)$$

where r_k is the impulse response in period k to the j-th shock of the size of one standard deviation and positive sign and u_j is $n \times 1$ vector of zeros except of a single 1 in the j-th entry (Uhlig, 2017). The sign restrictions then are imposed on the impulse responses r_k in the defined k horizons (Uhlig, 2017).

The results in this thesis are assessed using the impulse response functions and forecast error variance decompositions. The forecast variance decomposition indicates how much of the variable's variance is explained by the shock in the system, while the impulse response functions demonstrate how a shock in the system affects the current and future values of the variables in the system (Stock & Watson, 2001).

Table 4 presents the sign restrictions adopted in this thesis. Generally, the sign restrictions should be motivated by financial theory. As advised by Uhlig (2017), the restrictions imposed should be limited to those that are wellfounded. The sign restrictions adopted in this thesis have been motivated in section 2 using the theoretical frameworks proposed by Barro (2022) and Boehl (2022). Interpreting Table 4, a shock to the central bank balance sheet asset growth has a positive effect on the ex-ante growth rate and a negative effect on the ex-ante real interest rate, implied volatility, and dividend yield.

The method of Uhlig (2005) is a rejection method. The impulse responses are checked whether they match the imposed restrictions, and the response is kept if the signs match the restrictions (Uhlig, 2017). The sign restrictions are checked for the predetermined periods (Uhlig, 2017). However, determining the period in which the sign restrictions are imposed is rather arbitrary as similar strategies to choosing the VAR model lag length cannot be used to my knowledge. Also, there is no financial theory to motivate this choice. Therefore, I will use 6 periods ($K = 5$) to impose the sign restrictions on the variables in a similar fashion to Uhlig (2005) who also used the structural VAR model with 6 periods that the sign restrictions bound.

Table 4 Sign restrictions

Shock/Variable	g	r	σ	bs	dy
bs	≥ 0	≤ 0	⋛ 0	≥ 0	≤ 0
σ	≤ 0	≤ 0	≤ 0	≥ 0	≥ 0
dy	≤ 0	≥ 0	⋛ 0	≥ 0/⋛ 0	≥ 0

Notes: Sign restrictions on impulse responses when shock is happening in the variable on left. See variable definitions from Table 2.

5 RESULTS AND ANALYSIS

This section focuses on the results from the structural VAR models. Supplementary results, based on the standard VAR models are presented in Appendix 1 and Appendix 2 for the euro area and the US, respectively. Additionally, the cumulative impulse response functions and the variance decomposition tables for the structural VAR models are presented in the Appendices. The results for the structural VAR models are reported using 16 % and 84 % error bands following Uhlig's (2005) approach, and similar confidence intervals are used for the standard VAR models for coherence.

The results from the standard VAR models emphasis the necessity of employing the structural VAR models. While the standard models appear capable of depicting the impact of the shock, they fail to uncover the causal relationships between the variables. The following sections focus on these causal relationships which have been identified through the theoretical frameworks proposed by Barro (2022) and Boehl (2022) in section 2.

5.1 Results from the euro area structural VAR model

Figure 6 illustrates the orthogonal impulse response functions for the euro area structural VAR model when the other variables in the model are subject to a shock to the central bank balance sheet asset growth, and Panel A of Appendix 1, Table 1 presents the forecast error variance decompositions. After the shock, the ex-ante growth rate increases for six months, the central bank balance sheet asset growth for nine months, and the dividend yield shows a persistent decline for the one-year period ahead.

A comparison of the results to the unrestricted VAR model in Appendix 1, Figure 1 reveals several notable differences beyond the observed signs. First, unconventional monetary policy response is weaker in the structural VAR model than in the unrestricted VAR model. The peak central bank balance sheet asset growth is below 1 % in the structural VAR model, while the unrestricted VAR model exhibited a peak of over 2 %. Furthermore, the cumulative effect of the central bank balance sheet asset growth in the structural VAR model (Appendix 1, Figure 3) is 12.8 percentage points lower than that of the unrestricted VAR model (Appendix 1, Figure 2) with a total cumulative effect of 7.3 % one-year ahead. The shock to the central bank balance sheet asset growth explains 10.3 % of its own variance one-year ahead.

Second, in the structural VAR model, the behavior of implied volatility is more clearly mean-reverting behavior compared to the unrestricted model. Cumulatively, in the unrestricted VAR model, the unconventional monetary policy shock had initially a clear positive effect on implied volatility growth which turned negative after six months. However, the statistical significance in the unrestricted model was weak. In contrast, the structural VAR model displayed no statistically significant cumulative effect on implied volatility with the median effect varying around zero in the one-year ahead period.

Overall, the initial positive response observed in both structural and unrestricted models is noteworthy. Theoretically, the implied volatility should respond negatively to the unconventional monetary policy shock, as it should encourage saving in the economy for instance through confidence and signaling channels. However, the statistical significance of the initial positive response is weak.

The structural model shows larger effects on the ex-ante real interest rate compared to the unrestricted model, although the difference is minor. Nevertheless, both models exhibit similar ex-ante real interest rate responses.

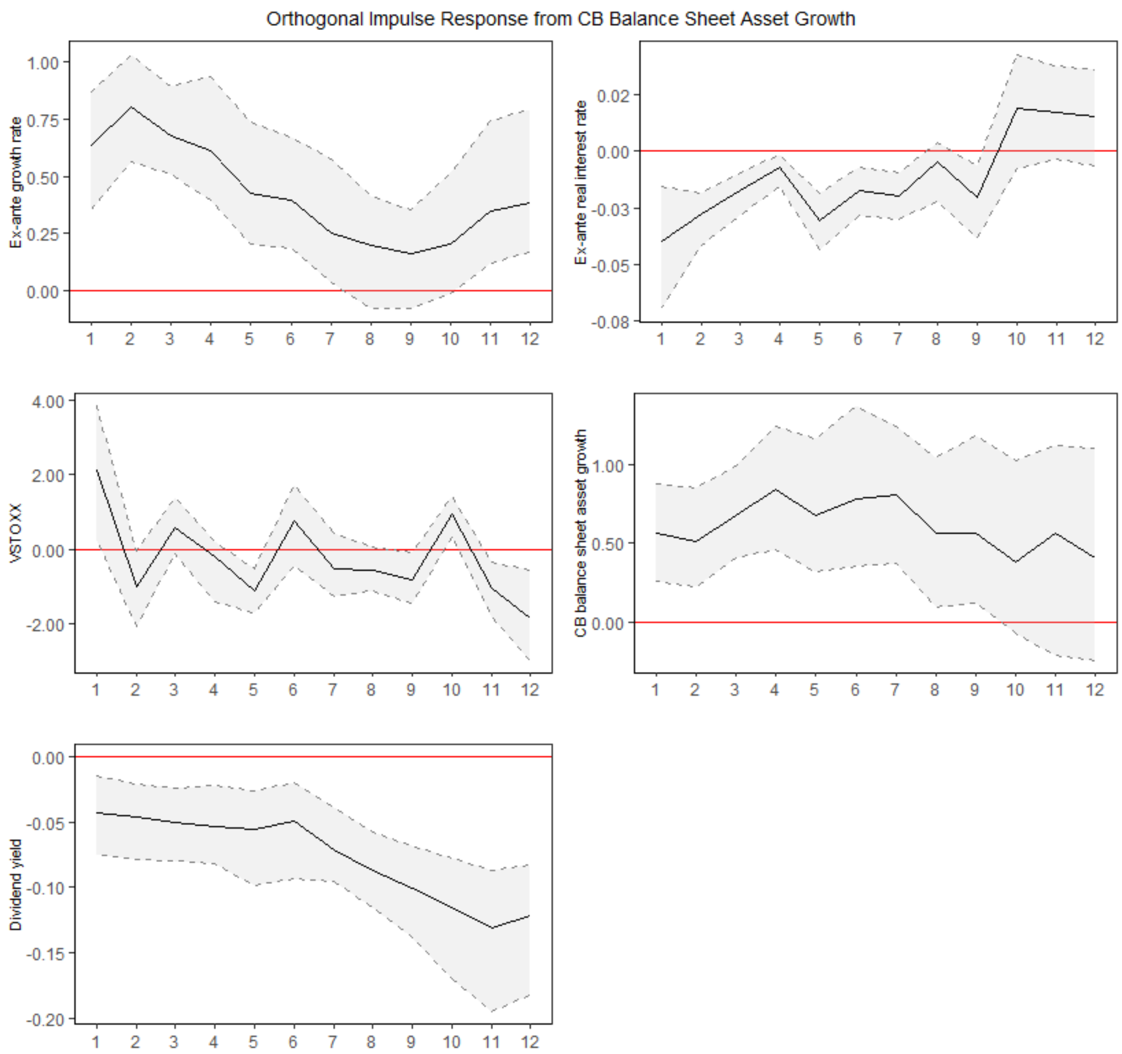

Figure 6 Impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in central bank balance sheet asset growth. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

The ex-ante growth rate response is stronger in the structural model. The cumulative one-year ahead median estimate for the ex-ante growth rate is 5.1 %, while the unrestricted model indicated no cumulative effect. The monetary policy shock explains 18.5 % of the variance in the ex-ante growth rate one-year ahead. In comparison Gambacorta et al. (2014) report that shock in central bank balance sheet assets explains only under ten percent of the variance in output.

The structural model provides a causal interpretation of the effects of unconventional monetary policy on dividend yield. In the unrestricted model, the dividend yield increased following the unconventional monetary policy, which may describe the data, but leaves the true relationship between the variables unanswered. In the structural model, the policy shock leads to a decline in dividend yield, with a gradually increasing effect over time. This indicates that the continuation of monetary easing has a positive and increasing effect on stock market valuations. This could be due to lower discount rates applied as also simultaneously the ex-ante real interest rate growth is negative for the first nine periods. The monetary policy shock explains 16.1 % of the dividend yield variance one-year ahead. The cumulative effect on dividend yield is -0.9 % one-year ahead with narrow error bands indicating increasing stock prices following the unconventional monetary policy shock.

Figure 7 displays the orthogonal impulse response functions for the euro area structural VAR model when the other variables in the model are subject to a shock to the implied volatility growth, and Panel B of Appendix 1, Table 1 presents the respective forecast error variance decompositions. The implied volatility again exhibits mean-reverting behavior. The error bands on the median estimate are large, and as shown in Appendix 1, Figure 6, the cumulative median estimate is not different from zero after the first month. Overall, the response of the implied volatility growth to a shock on itself is fairly similar in both the unrestricted and structural models.

Compared to the unrestricted model, the central bank balance sheet asset growth exhibits a stronger response to the implied volatility growth shock in the structural model. The central bank balance sheet asset growth remains positive for 11 months after the shock. Cumulatively this effect is around 4 % higher in the structural model, resulting in a total central bank balance sheet asset growth of 13.8 % one-year ahead in response to the implied volatility growth shock. The implied volatility growth shock explains 18.4 % of the variance in central bank balance sheet asset growth one-year ahead.

The implied volatility growth shock has a positive and persistent effect on dividend yield, with a cumulative impact of approximately 0.9 % one-year ahead. The implied volatility shock explains 13.2 % of the dividend yield variance one-year ahead. Compared to the unrestricted model, the structural model shows a significant response in dividend yield to the implied volatility shock. In contrast, the unrestricted model seems to reflect the combined and cancelling effects of the shock and resulting quantitative easing from the central bank.

The ex-ante growth rate decreases for seven months. While the implied volatility growth shock explains 9.2 % of the ex-ante growth rate variance one-year ahead, its explanatory power is considerably lower than that of the monetary policy shock. Compared to the unrestricted model, the cumulative effect on the ex-ante growth rate is smaller in the structural model. The cumulative one-year ahead median estimate for the ex-ante growth rate is -2.5 % compared to the -3.2 % in the unrestricted model. The ex-ante real interest rate does not exhibit a significant initial response to the implied volatility growth. Although the response becomes significant between the second and sixth periods, it remains marginal.

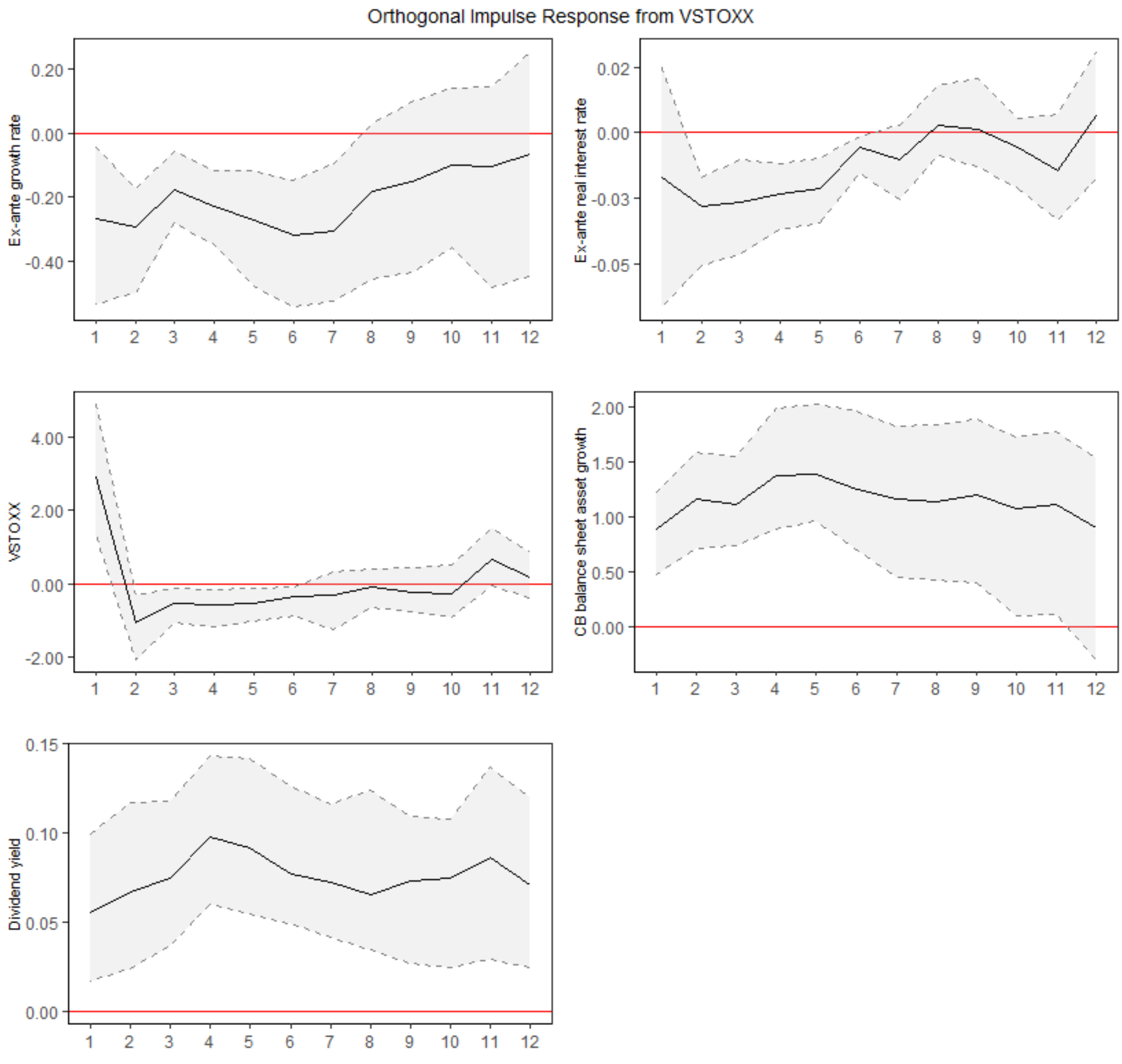

Figure 7 Impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in VSTOXX. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

Figure 8 shows the orthogonal impulse response functions for the euro area structural VAR model when the other variables in the model are subject to a shock to the dividend yield, and Panel C of Appendix 1, Table 1 presents the respective forecast error variance decompositions. The cumulative impact is shown in Appendix 1, Figure 9. Notably, the dividend yield curve is inverted compared to that of the unrestricted model in Appendix 1, Figure 7. Despite this difference, the total one-year ahead cumulative effect remains consistent across both the unrestricted and the structural model, at approximately 0.9 %.

In the structural model, the implied volatility growth does not seem to be affected by the shock on the dividend yield. The effect of the dividend yield shock on the ex-ante growth rate is rather strong and persistent, with a one-year ahead cumulative effect of -5.4 %. The effect on the ex-ante real interest is again relatively small but still significant.

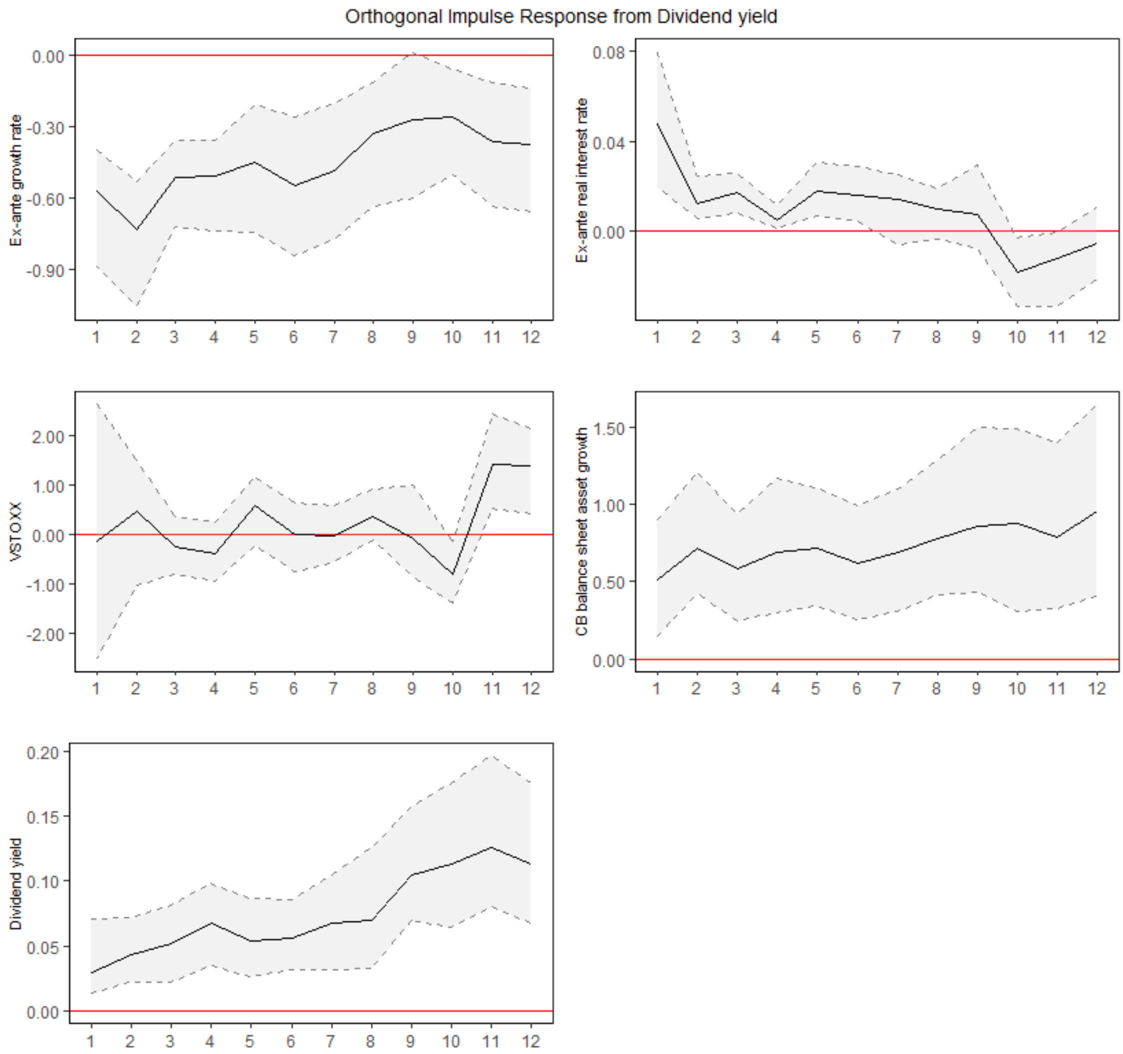

Figure 8 Impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in dividend yield. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

The positive growth in the ex-ante real interest rate indicates also that the discount rates used to the valuation of stock market assets also increase after a negative stock market valuation shock. This may explain the increasing trend of the dividend yield along with lower growth expectations.

The central bank balance sheet asset growth is moderate when assuming that the central bank reacts to stock price deviations. The one-year ahead cumulative effect on the central bank balance sheet asset in the structural model is rather large at 8.8 %.

However, when lifting the assumption that the central bank responds to the large stock market deviations, in other words unrestricting the central bank balance sheet asset growth response given in Table 4, the effects change. Figure 9 shows the orthogonal impulse response functions for the euro area structural VAR model to a shock to the dividend yield when the sign of central bank balance sheet asset growth is unrestricted.

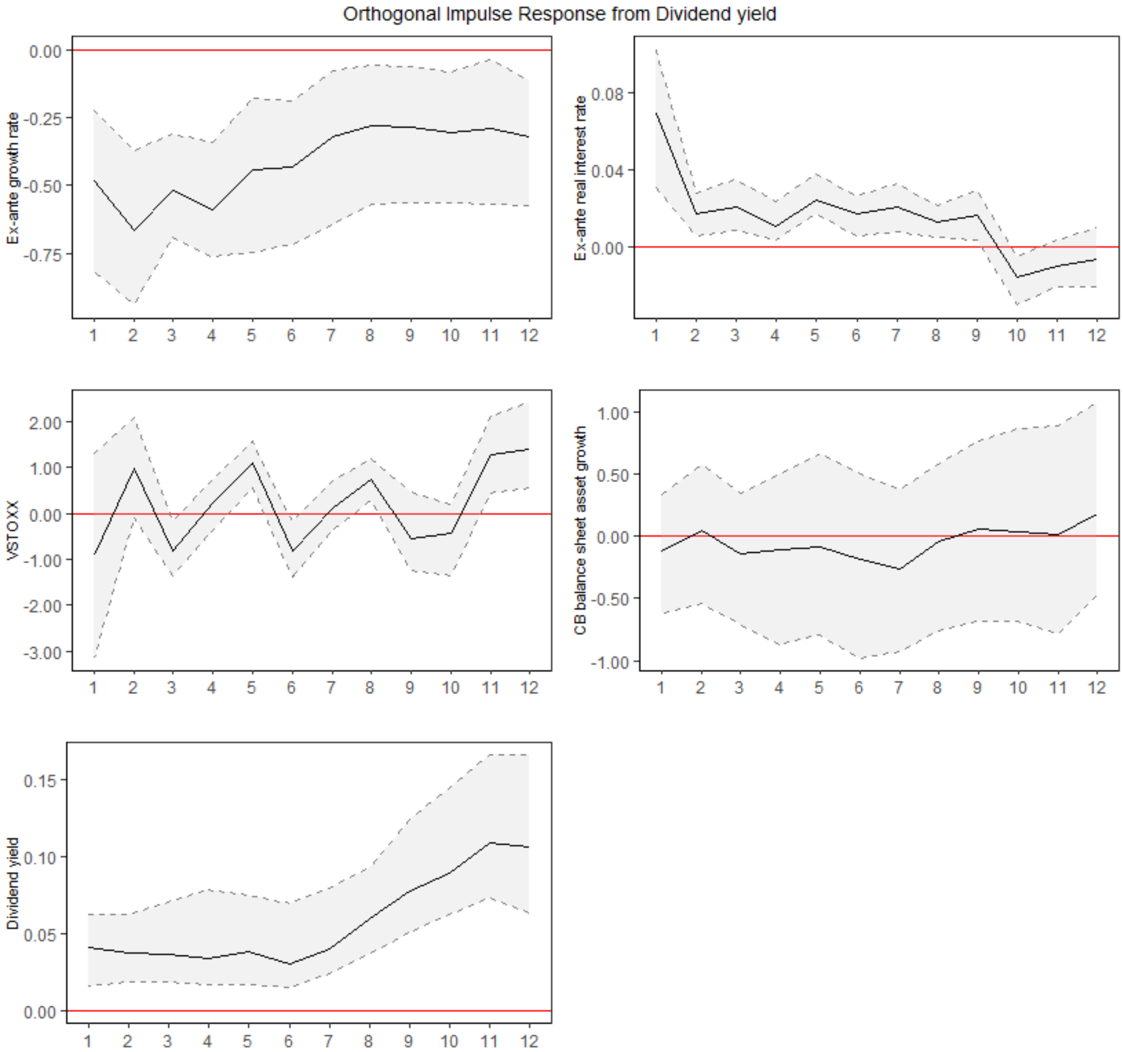

Figure 9 Impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in dividend yield with unrestricted *bs*. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

One clear difference between Figure 8 and Figure 9 is that after unrestricting the central bank balance sheet asset growth its impulse response function goes to zero. In other words, the central bank does not respond to the asset price deviation. When the central bank does not respond to asset price fluctuations the adverse effects on the economy are smaller. The cumulative effect in Appendix 1, Figure 9 on the ex-ante growth rate is -4.9 %, 0.5 percentage points smaller than in the more restricted model.

The dividend yield shows a smaller cumulative increase in the less restricted model, with a 0.7 % higher one-year ahead effect that is 0.2 percentage points lower than in the more restricted model. The less restricted model provides a more accurate estimation of the effect on the implied volatility growth, but the cumulative effect remains zero.

The variance decomposition results are similar for both models when the other variables in the model are subject to the dividend yield shock. The dividend yield shock explains approximately 19.5 % of the ex-ante growth rate variance, 9.9-11.0 % of the variance in central bank balance sheet asset growth, and 13.6-14.3 % of its own variance one-year ahead.

This, therefore, indicates that even though the central bank may be tempted to easen the monetary policy following a negative stock market valuation shock, it should avoid doing so, as such actions may actually exacerbate the negative effects of the shock.

5.2 Results from the US structural VAR model

Figure 10 shows the orthogonal impulse response functions for the US structural VAR model when the other variables in the model are subject to a shock to the central bank balance sheet asset growth, with the cumulative effect shown in Appendix 2, Figure 1. Panel A of Appendix 2, Table 1 presents the respective forecast error variance decompositions. The shock leads to an increase in the ex-ante growth rate and central bank balance sheet asset growth increase, as well as a decrease in dividend yield. These effects are persistent for the one-year ahead period.

The trend of central bank balance sheet asset growth is increasing in the structural model, while it was decreasing in the standard VAR model. However, the trend is less pronounced in the structural model. The one-year ahead cumulative effect on the central bank balance sheet asset growth in the structural model is 13.8 %, which is 8.1 percentage points lower than in the unrestricted model. The central bank balance sheet asset growth shock in the US model explains 12.9% of its own variance one-year ahead, which is slightly higher than in the euro area.

The implied volatility growth shows mean reversion with point estimates not significantly different from zero except for one period. The effect on the dividend yield is marginal, with a total cumulative effect of only -0.3 %

one-year ahead which is significantly lower compared to the euro area. One-year ahead, the central bank balance sheet asset growth shock explains 10.9 % and 14.1 % of the variance in implied volatility growth and dividend yield, respectively.

The unconventional monetary policy shock has a stable effect on the ex-ante growth rate, with a median estimate between 0.20 % and 0.30 % per period, resulting in a cumulative increase of 3.0 % in the ex-ante growth rate one-year ahead. However, in the US model, the central bank balance sheet asset growth explains only 11.4 % of the ex-ante growth rate variance one-year ahead which is 7.1 percentage points lower than in the euro area. The effect on the ex-ante real interest rate is small and significant for six months. The one-year ahead cumulative effect on the ex-ante real interest rate growth rate is not different from zero.

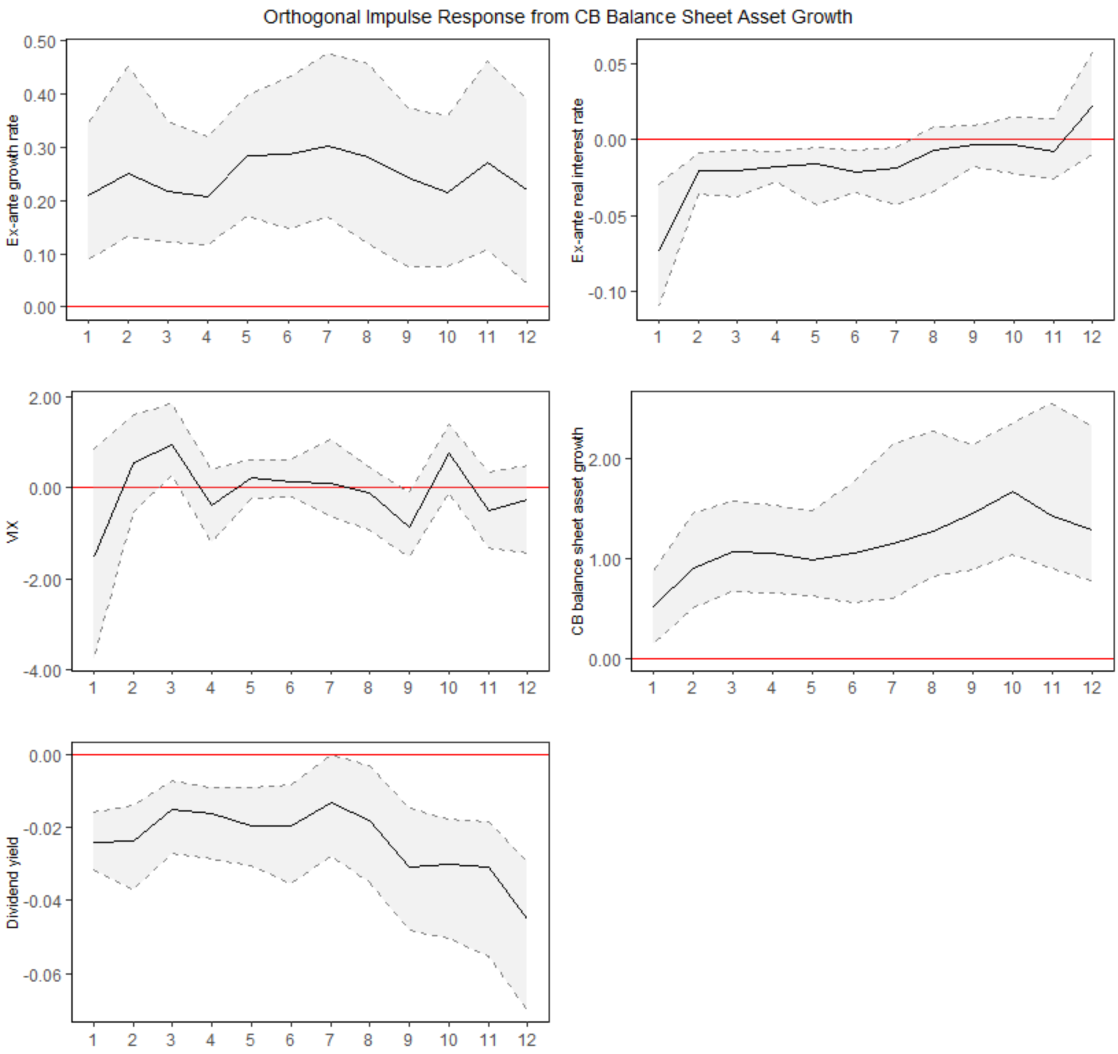

Figure 10 Impulse response functions with 100 draws kept for the US structural VAR model to a shock in central bank balance sheet asset growth. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

However, again as with the euro area model, the negative ex-ante interest rate growth may partly explain the positive effects on the stock market valuations. In other words, as the real interest rate declines following the unconventional monetary policy shock, discount rates used in the valuation of stock market assets decrease, resulting in a positive effect on the valuations. Similarly, the positive effect on the ex-ante growth rate may decrease the discount rates used in stock valuations.

Figure 11 shows the orthogonal impulse response functions for the US structural VAR model when the other variables in the model are subject to a shock to the implied volatility growth, with the cumulative impact shown in Appendix 2, Figure 6. Panel B of Appendix 2, Table 1 presents the respective forecast error variance decompositions. The implied volatility growth again exhibits mean-reverting behavior. The central bank balance sheet asset growth increases persistently in response to the implied volatility shock with a total cumulative effect of 5.7 %. The implied volatility growth shock explains only 8.9 % of the variance in the central bank balance sheet asset growth one-year ahead in the US which is 9.5 percentage points lower than in the euro area model.

The effect on dividend yield is higher and persistent in the structural model compared to the unrestricted model. Furthermore, the total cumulative effect on dividend yield is greater in the structural model, with one-year ahead effect of 0.4 % which is 0.2 percentage points higher than in the unrestricted model. This indicates that the standard VAR model is able to already capture some of the mitigating effects of unconventional monetary policy on stock market valuations. The implied volatility growth shock explains 14.0 % of the variance in dividend yield one-year ahead.

The response of the ex-ante growth rate to the implied volatility growth shock is negative, stable, and persistent for the one-year ahead period. The implied volatility growth shock explains 12.7 % of the ex-ante growth rate variance one-year ahead. The cumulative effect of the shock results in a decline of -3.7 % in the ex-ante growth rate. The cumulative effect on the ex-ante real interest rate growth is not significant from zero.

Figure 12 shows the orthogonal impulse response functions for the US structural VAR model when the other variables in the model are subject to a shock to the dividend yield with the cumulative impact shown in Appendix 2, Figure 9. Panel C of Appendix 2, Table 1 presents the respective forecast error variance decompositions. The impact on the dividend yield is persistent over the one-year estimation period. Although the effects are slightly larger than those in the unrestricted model, the difference is not significant from an economic perspective. The total one-year ahead cumulative effect on dividend yield in the structural model is 0.9 %.

The median estimate for the implied volatility growth in the structural model is not significantly different from zero in any period. This is in contrast to the unrestricted model where the implied volatility growth varied substantially. Although the central bank balance sheet asset growth is positive in the structural model, its cumulative size one-year ahead is not statistically significant from zero.

The effect on the ex-ante growth rate is stable and persistently negative, resulting in a cumulative decline of 2.5 % one-year ahead. The dividend yield shock has a positive effect on the ex-ante real interest rate, resulting in a cumulative growth of 0.4% one-year ahead.

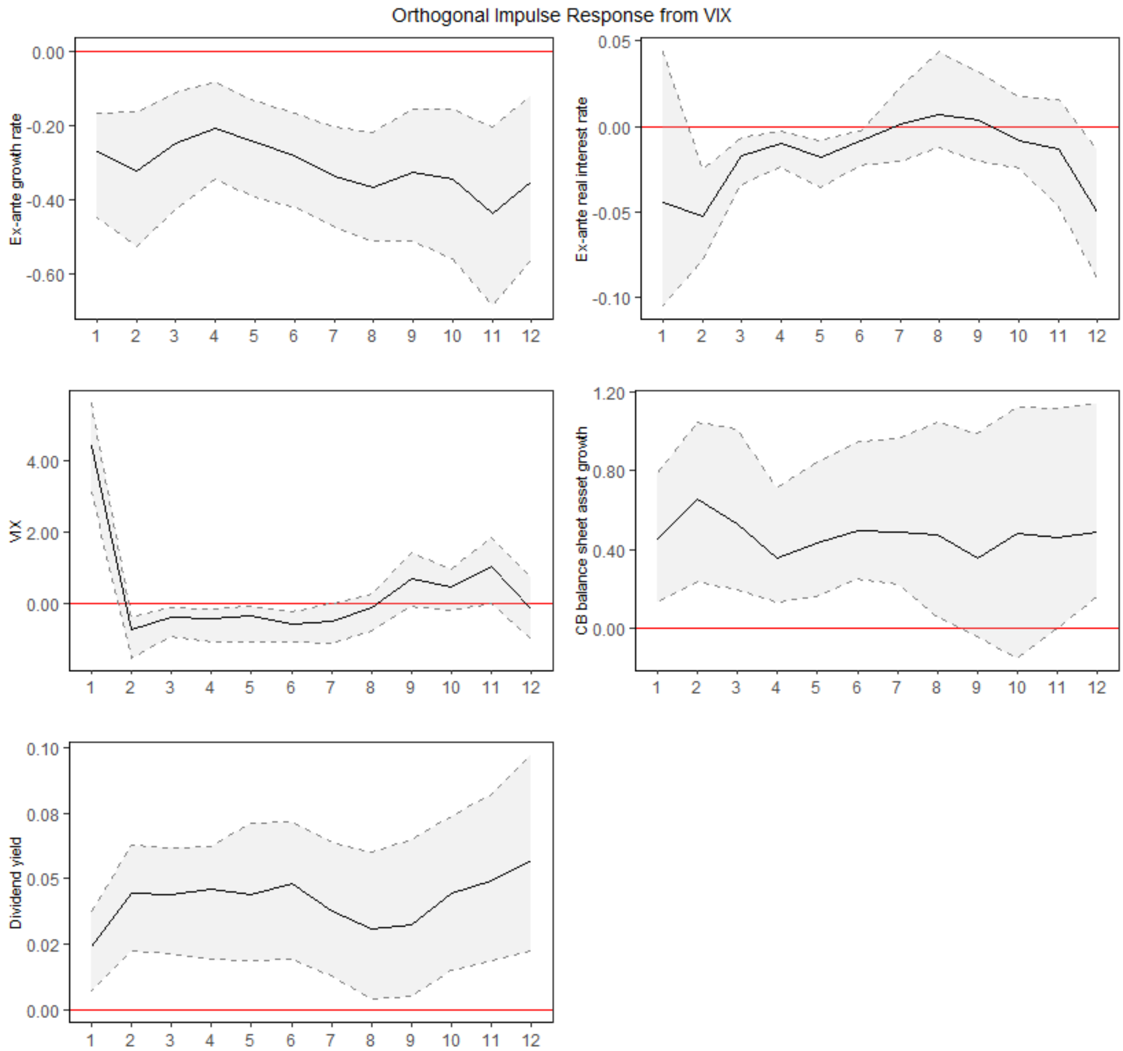

Figure 11 Impulse response functions with 100 draws kept for the US structural VAR model to a shock in VIX. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

Figure 13 shows the orthogonal impulse response functions for the US structural VAR model when the other variables in the model are subject to a shock to the dividend yield when the sign of central bank balance sheet asset growth is, and Panel D of Appendix 2, Table 1 presents the respective forecast error variance decompositions. The cumulative impact is shown in Appendix 2, Figure 10. The figure suggests that when stock prices decline in the US, the central bank tightens its monetary policy. The total cumulative effect of the dividend yield shock to the central bank balance sheet asset growth is -13.1 %.

Although the central bank balance sheet asset growth is negative, its impact on the cumulative effects of other variables is negligible. The effect on the ex-ante real interest rate and dividend yield decreases by 0.1 percentage points and 0.3 percentage points respectively while the ex-ante growth rate decreases by 0.1 percentage points compared to the more restricted structural model.

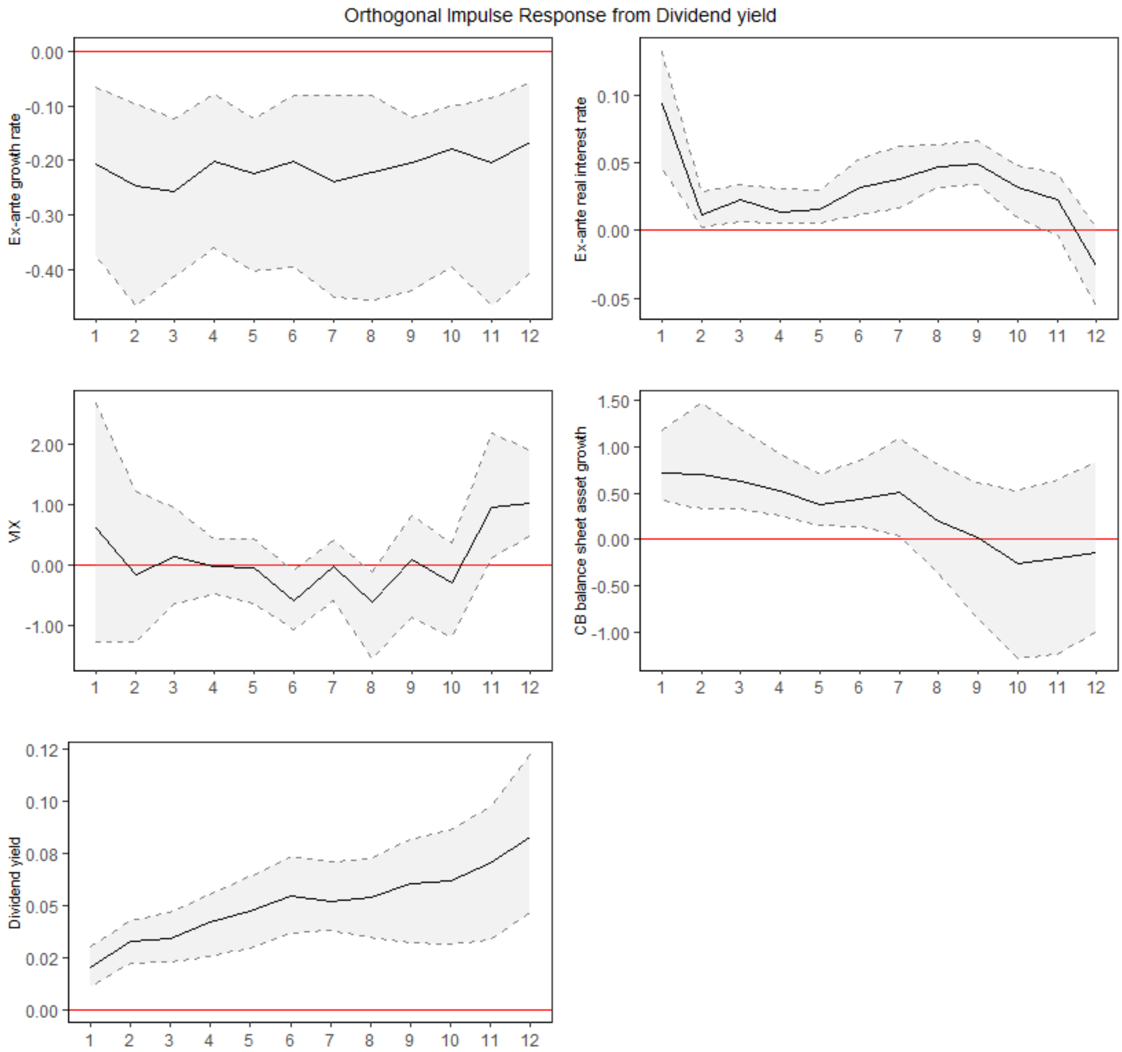

Figure 12 Impulse response functions with 100 draws kept for the US structural VAR model to a shock in dividend yield. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

These findings provide us with the same conclusion as the findings from the euro area models. Also, in the case of the US overall economy is better off when the central bank does not easen the monetary policy. Furthermore, the mechanisms causing the increasing trend for the dividend yield seem to be similar for the US in comparison with the euro area. In other words, increasing ex-ante real interest rate with negative effects on the ex-ante growth rate cause the discount rates used in the stock market valuations to increase further decreasing the valuations.

The dividend yield shock explains 8.7-9.7 % of the ex-ante growth rate variance which is almost ten percentage points lower than in the euro area model. On the other hand, the dividend yield shock explains 10.8-13.9 % of the variance in central bank balance sheet asset growth and approximately 13.8 % of its own variance one-year ahead which are both higher compared to the euro area model.

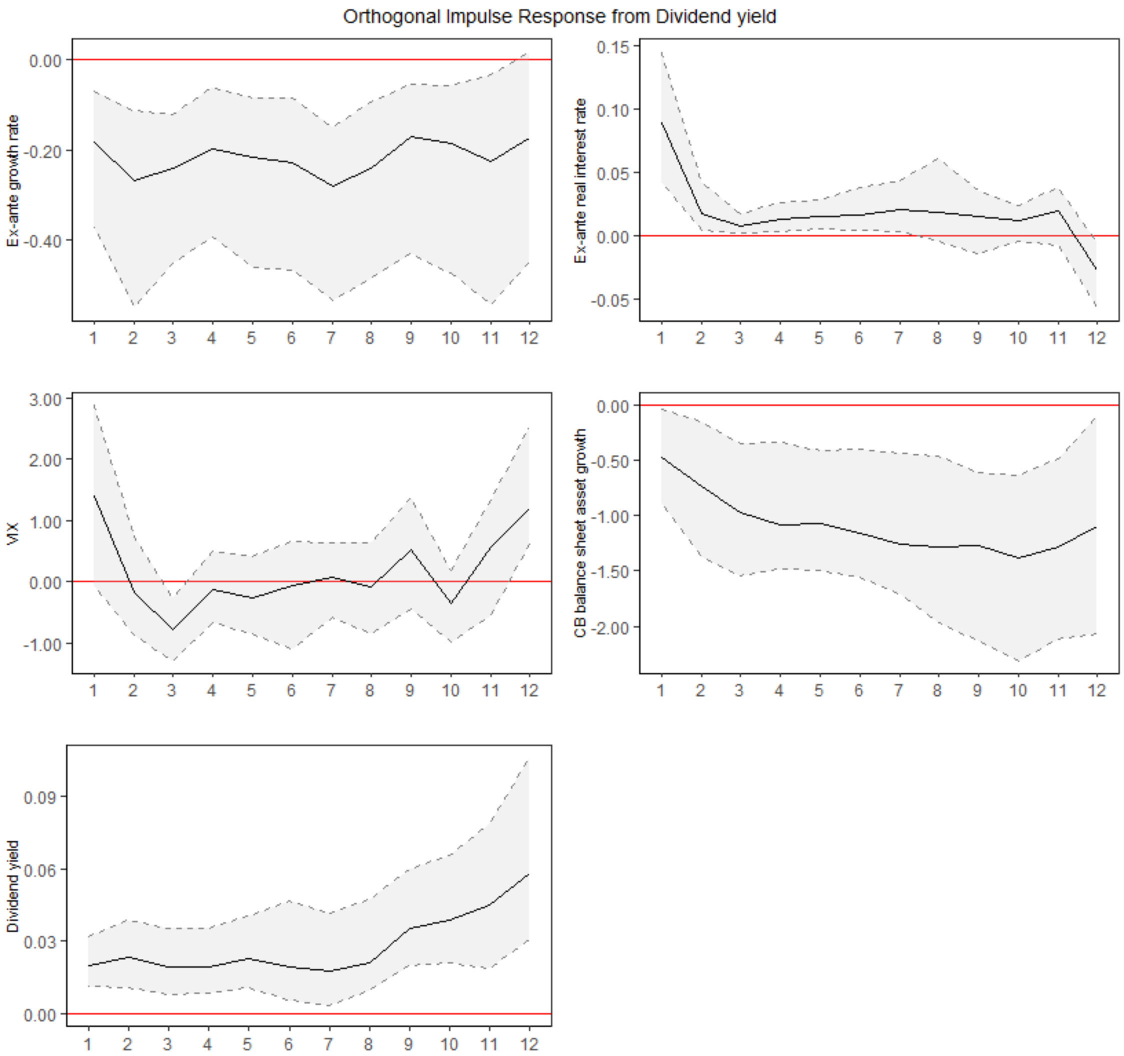

Figure 13 Impulse response functions with 100 draws kept for the US structural VAR model to a shock in dividend yield with unrestricted *bs*. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

5.3 Discussion and comparison with previous studies

From the results, three general findings arise. Firstly, the impulse response functions of the structural VAR models show that the effects in the euro area are generally more pronounced, both period-per-period and cumulatively, compared to the US. This finding is contrary to the previous literature, which suggests larger effects in the US (Gambacorta et al., 2014; Papadamou et al., 2019). One reason for this difference could be the extended data period in this thesis which covers the COVID-19 pandemic. However, the same cannot be said about the standard VAR models which indicate approximately similar effects for both regions.

Secondly, the implied volatility in all cases displays mean reversion, and the overall effect on the ex-ante real interest rate is economically insignificant over the one-year horizon.

Thirdly, the effects on the ex-ante growth rate, central bank balance sheet asset growth, and dividend yield are persistent, while the effects on the ex-ante real interest rate are transient. This aligns with previous literature that highlights the persistence of the effects following unconventional monetary policy shocks (see e.g. Altavilla & Giannone, 2017; Altavilla et al., 2019; Swanson, 2021; Neely, 2022).

The positive effects in the structural VAR models are greater for the euro area after a shock in the central bank balance sheet asset growth. This is somewhat surprising considering that in structural VAR models, the Fed's balance sheet experienced a larger cumulative growth of 13.8 %, compared to the ECB's 7.8%. The cumulative effect of the ex-ante growth rate is only 3.0% in the US while it increases by 5.1 % increase in the euro area. The dividend yield decreases by only 0.3 % in the US, whereas it drops by 0.9 % in the euro area, indicating that stock prices increase more significantly in the euro area, as a result of unconventional monetary policy shock.

Therefore, if the unconventional monetary policy shock is unexpected, its effects on the euro area are considerably better than in the US. Additionally, the economically significant increases in the ex-ante growth rate identified by the structural VAR models could be used to explain the continued use of quantitative easing programs by central banks.

When the shock happens in the implied volatility, the US experiences a larger negative cumulative effect on the ex-ante growth rate compared to the euro area. The ex-ante growth rate decreases by 3.7 % in the US and only 2.5 % in the euro area while the cumulative central bank balance sheet asset growth is 13.8 % in the euro area and 5.7 % in the US. Dividend yield, however, increases more in the euro area compared to the US. Therefore, contrary to the case of unexpected unconventional monetary policy shock, the reactionary unconventional monetary policy response in the US is more effective in mitigating the adverse effect on the economy.

Overall, these results in this thesis are consistent with prior research by Kapetanios et al. (2012), Baumeister & Benati (2013), Gambacorta et al. (2014), Hesse et al. (2018), and Mouabbi & Sahuc (2019) which suggest that unconventional monetary policy has a positive effect on the economy. Moreover, the results in this thesis demonstrate that balance sheet extension can effectively mitigate adverse effects on the ex-ante growth rate, whether the unconventional monetary policy shock is unexpected or reactionary to other shocks.

Considering the relationship between implied volatility shock and the macroeconomy, the results in this thesis follow the results of previous literature (Altig et al., 2020; Urom et al., 2021; Kumar et al., 2022), which has suggested a negative relationship between the implied volatility shock and growth rate.

The results in this thesis provide contradicting view against the results of Bekaert et al. (2013), who suggest that the uncertainty component of the implied volatility decreases following an unconventional monetary policy shock, leading to a decrease in implied volatility. Contrary to this, the results of this thesis suggest that implied volatility does not change following unconventional monetary policy shock. However, the results of Bekaert et al. (2013) become statistically significant only after nine to twelve months following the shock depending on their model specification, which aligns with the conclusion of this thesis for the one-year ahead period.

One key finding in this thesis is that, in both regions, the overall economy is better off when the central bank does not ease the monetary policy after an adverse to the stock market valuations. This conclusion is supported by the results of the different iterations of the structural VAR models when a shock occurs in the dividend yield.

However, the inference drawn from the results differs slightly between the two regions. In the case of the euro area, the results suggest that the economy is better off when the central bank does not respond at all. In contrast, for the US, results indicate that the economy is better off when the central bank *tightens* the monetary policy. However, these results are sensitive to the specification of the structural model. When the sign restrictions are imposed for the whole one-year ahead period, the results for the US are similar compared to the euro area.

Therefore, this finding provides a supporting view to the previous leaning against the wind literature (Galí, 2014; Svensson, 2014, 2017; Boehl, 2022), however, looking at the phenomenon from an inverse perspective. Overall, the findings from this thesis, along with previous literature, suggest that the central bank should not adapt the monetary policy to varying stock market conditions.

The degree of uncertainty towards the longer horizon in this thesis is generally equivalent to that of the shorter horizons, as per Uhlig (2005). However, the error bands for the median estimate are not always symmetrical. In several instances, when the median estimate is positive, the upper error bands are wider than the lower error band, and vice versa when the median is negative.

As in Uhlig (2005), the identification process of the sign restrictions in this thesis could be described as depicting the consensual views of the identified shock to the variables. Considering the differences between the standard VAR models and the structural VAR models, the structural model seems appealing as the impulse response functions in the standard VAR model can produce signs that are inconsistent with the consensus views. However, there are two degrees of choice in this thesis regarding the structural VAR models that could be open to question.

First, one potential area of concern with the structural VAR models used in this thesis is the choice of the horizon K that the sign restrictions bounded. Following Uhlig (2005), I use K=5 in this thesis to restrict the signs for the first six months. However, as demonstrated in the case of the US structural model for the shock in dividend yield, the results can be sensitive to the choice of K.

Second, the choice of restricting the central bank balance sheet asset growth when a shock occurs in the implied volatility may be subject to question. While the choice of restricting the central bank balance sheet asset growth was made based on the trend illustrated in Figure 1 and Figure 2, it can also be motivated by the equation system of Boehl (2022), assuming that in the central bank reaction function in equation (15) the policy parameter φ_s is non-zero.

6 CONCLUSIONS

This master's thesis has studied the effects of unconventional monetary policy on stock market valuations and the real economy. This has been done using standard VAR and structural VAR models with data from 2004 to 2021 in the euro area and the US. This thesis contributes to the existing literature by studying the dynamic relationships between the real economy, stock market valuations, and unconventional monetary policy while incorporating rare disaster risk proxied by implied volatility into the models. As for my knowledge, this has not been done in literature previously. Moreover, this thesis covers the COVID-19 period which is not found in any comparable previous research.

One of the key findings of this thesis is that the negative impact of the negative stock market shock on both stock market valuations and the real economy is reduced when the central bank refrains from implementing an easing monetary policy. This result is particularly evident in the case of the euro area. While the results are less clear for the US, they still suggest similar conclusions. This finding adds to the previous literature on leaning against the wind policies which has argued that when stock market valuations increase the central bank should not employ tightening monetary policy. The finding in this thesis reinforces this view suggesting that, regardless of stock market developments, the central banks should not change their monetary policy in response to them.

This thesis also finds that an exogenous unconventional monetary policy shock has a positive and persistent effect on stock market valuations for both the euro area and the US. Moreover, the ex-ante growth rate is positively affected in both regions, albeit the effects are transient for the US. On the other hand, when an exogenous implied volatility shock occurs, it causes a persistent negative effect on stock market valuations and ex-ante growth rate. It also causes a moderately persistent positive effects on unconventional monetary policy. Furthermore, the effects on the ex-ante real interest rate and implied volatility are relatively consistent across the model specifications. The effects on ex-ante real interest rate are marginal and transient whereas implied volatility exhibits mean-reverting behavior.

While the data sample used in this thesis covers the period of the COVID-19 crisis it leaves unanswered the potential direct effects of the pandemic on the dynamic relationships between the unconventional monetary policy, stock market, and real economy. Thus, future research could add to the present thesis by explicitly investigating the effects that the inclusion of COVID-19 period data has on the findings presented here. Additionally, replicating the results in this thesis using an alternative proxy for rare disaster risk, such as the CISS indicator, could be interesting.

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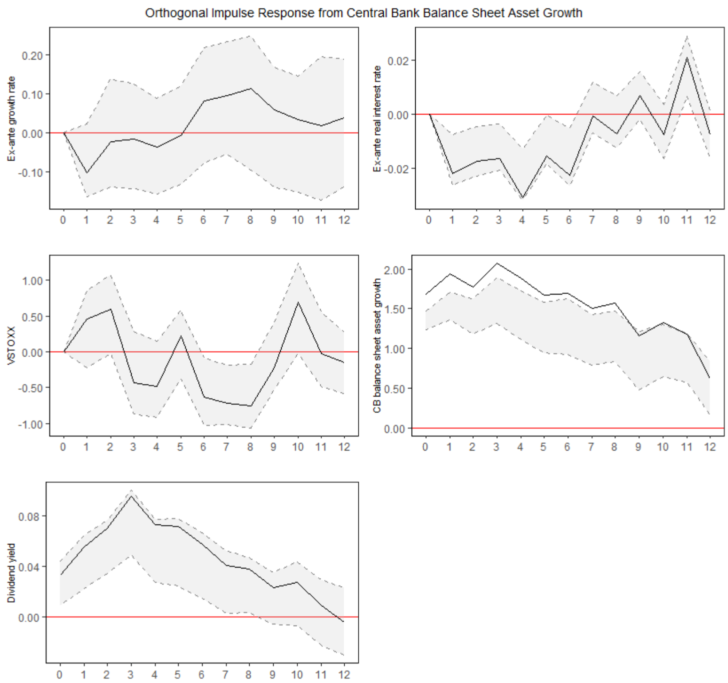
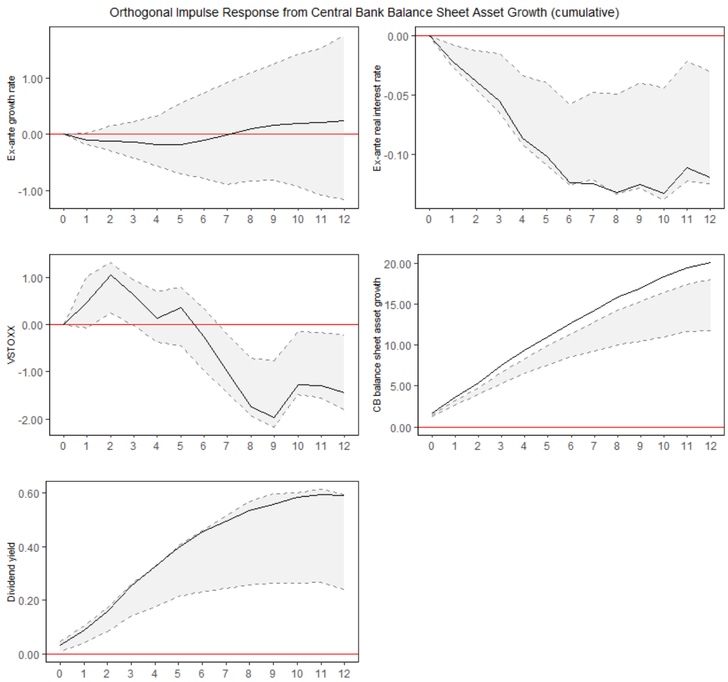
APPENDIX 1 Euro area results from the standard VAR model and additional Tables and Figures

Appendix 1, Figure 1 illustrates the orthogonal impulse response functions for the euro area VAR model when the other variables in the model are subject to a shock to the central bank balance sheet asset growth. The impulse responses indicate initial negative responses for ex-ante growth rate and ex-ante real interest rate while positive responses for implied volatility, central bank balance sheet asset growth, and dividend yield. The impulse responses for the ex-ante growth rate are not statistically significant at any point for the one-year ahead period and implied volatility growth becomes significant only after six months. However, these findings contradict the sign restrictions identified in Table 4, where three out of the five impulse responses show reactions that are opposite to the expected responses.

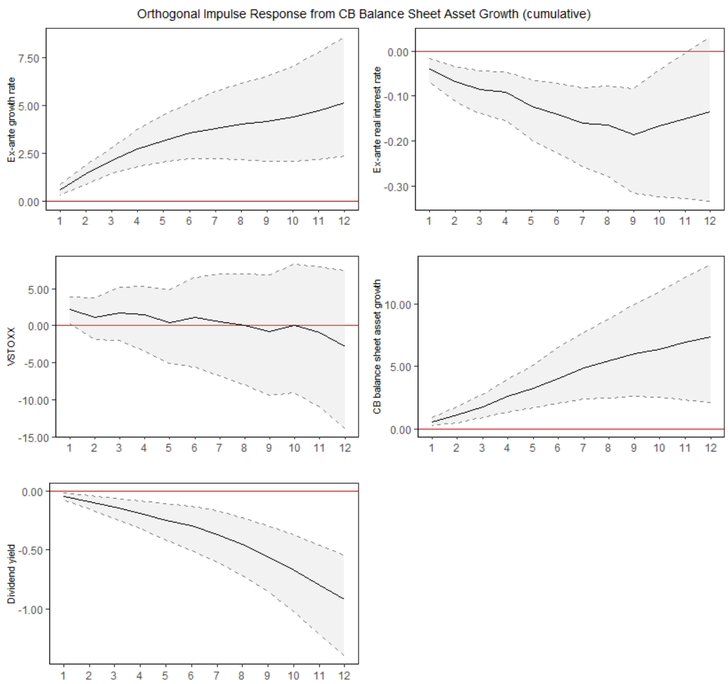
Unconventional monetary policy shock implies continuing growth of the central bank balance sheet assets in the euro area for at least one year forward. The ex-ante real interest decreases for six months, which indicates higher inflation in the zero-lower-bound. Dividend yield grows for the seven months indicating that stock prices decline as a result of unconventional monetary policy shock. This seems theoretically strange as, at the same time, the ex-ante real interest rate declines. When the ex-ante real interest rate declines, investors should discount investment at lower rates, leading to higher valuations.



Appendix 1, Figure 1 Impulse response functions for 1000 runs for the euro area VAR model to a shock in central bank balance sheet asset growth. 68 % bootstrap confidence interval as shaded area.



Appendix 1, Figure 2 Cumulative impulse response functions for 1000 runs for the euro area VAR model to a shock in central bank balance sheet asset growth. 68 % bootstrap confidence interval as shaded area.

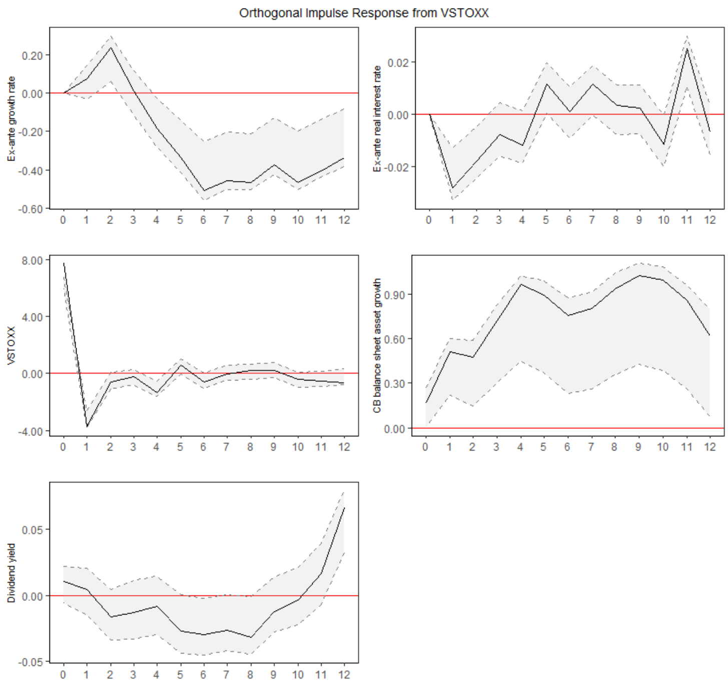


Appendix 1, Figure 3 Cumulative impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in central bank balance sheet asset growth. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

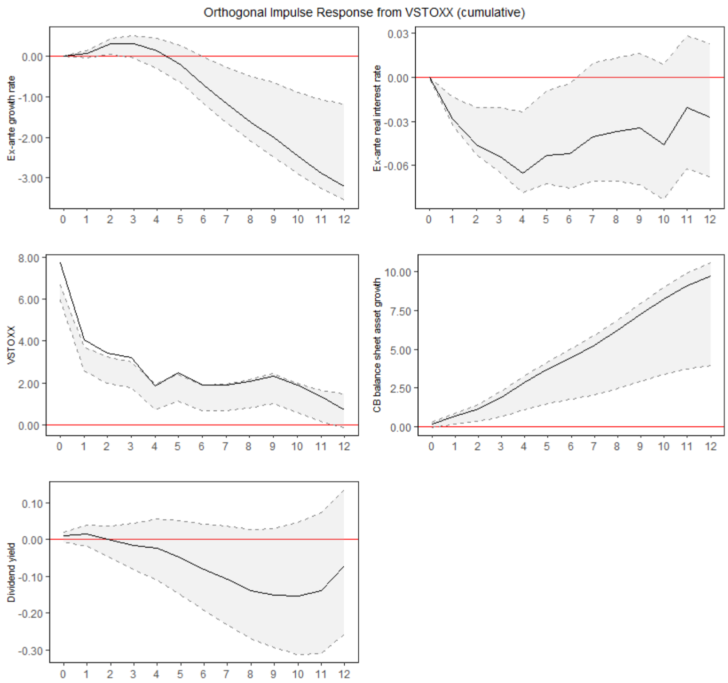
Appendix 1, Figure 4 shows the orthogonal impulse response functions for the euro area VAR model when the other variables in the model are subject to a shock to the implied volatility growth. The impulse responses to implied volatility align better with the theoretical signs. Quantitative easing has a positive response to implied volatility shock, and its cumulative effect is rather large.

The effect on dividend yield is negative after an initial positive reaction. This implies that initially stock prices decline but quickly recover and even slightly increase. However, this effect is marginal and not statistically significant.

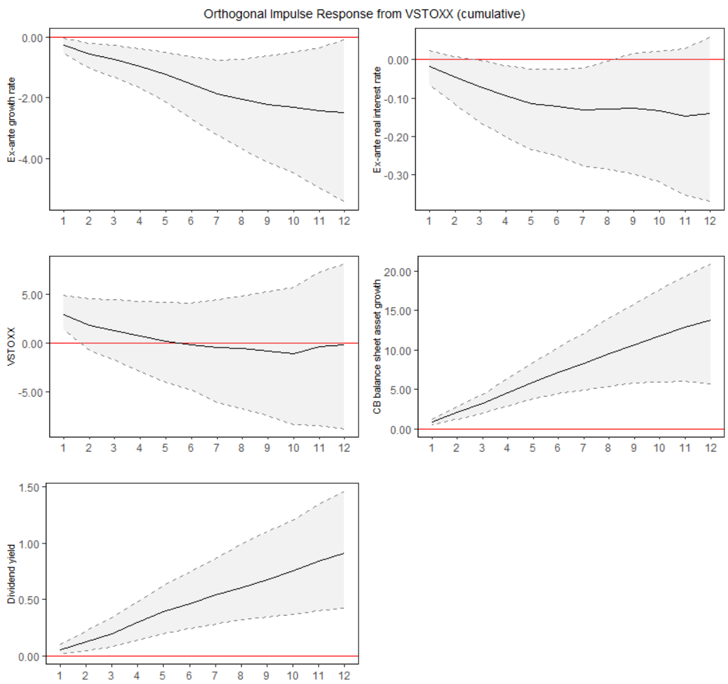
The ex-ante real interest rate declines following the implied volatility shock, but the effect is overall very small, only hundreds of percentage points in magnitude. Interestingly, the ex-ante growth rate initially increases but turns negative after one quarter. This seems counterintuitive in the theoretical sense. If anything, the responses should be inverted, as when implied volatility increases, the ex-ante growth should initially decrease. Additionally, if the central bank balance sheet asset growth develops as in Appendix 1, Figure 4, the ex-ante growth rate should turn positive as the result of the easing monetary policy.



Appendix 1, Figure 4 Impulse response functions for 1000 runs for the euro area VAR model to a shock in VSTOXX. 68 % bootstrap confidence interval as shaded area



Appendix 1, Figure 5 Cumulative impulse response functions for 1000 runs for the euro area VAR model to a shock in VSTOXX. 68 % bootstrap confidence interval as shaded area.



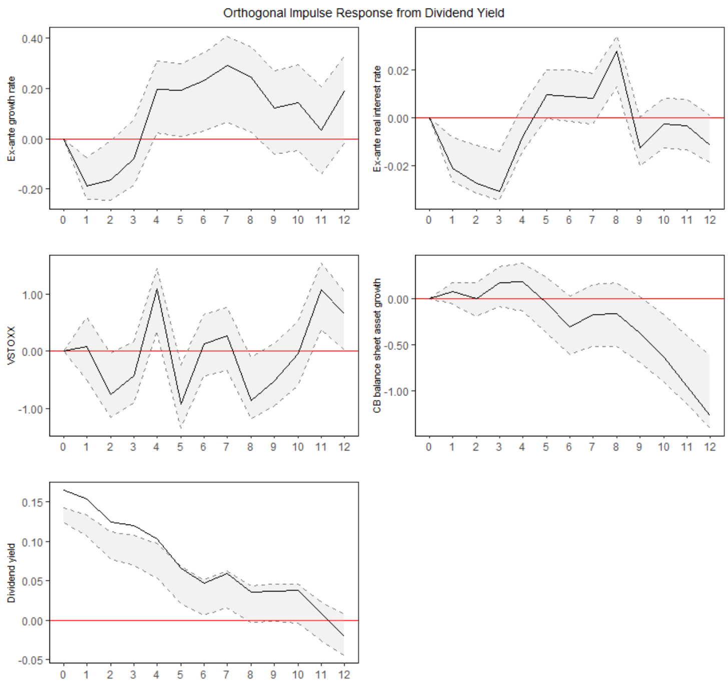
Appendix 1, Figure 6 Cumulative impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in VSTOXX. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

Appendix 1, Figure 7 presents the orthogonal impulse response functions for the euro area VAR model when the other variables in the model are subject to a shock to the dividend yield. In other words, the shock to the dividend yield results from a negative shock to stock prices, given that the dividends are relatively slow-moving.

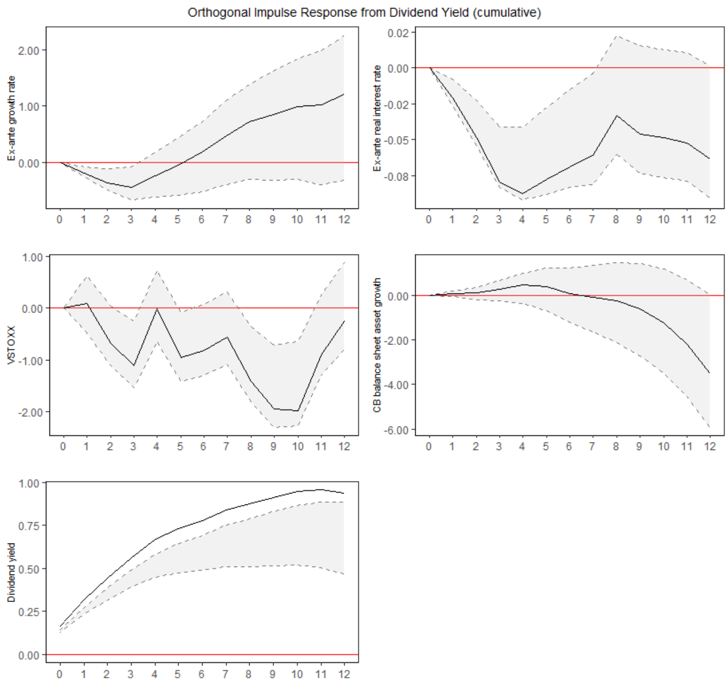
The shock to the dividend yield seems to impact itself for almost a year forward. Thus, a large initial stock price decline suggests continuing stock price declines. Initially, unconventional monetary policy does not react to the dividend yield shock which is in line with the leaning against wind literature. However, after three-quarters Appendix 1, Figure 7 indicates quantitative tightening.

After a shock to the dividend yield, both the ex-ante growth rate and ex-ante real interest rate exhibit a similar initial response of decline, followed by a subsequent recovery after approximately one quarter. However, the cumulative effect on the ex-ante growth rate is positive and negative for the ex-ante real interest rate.

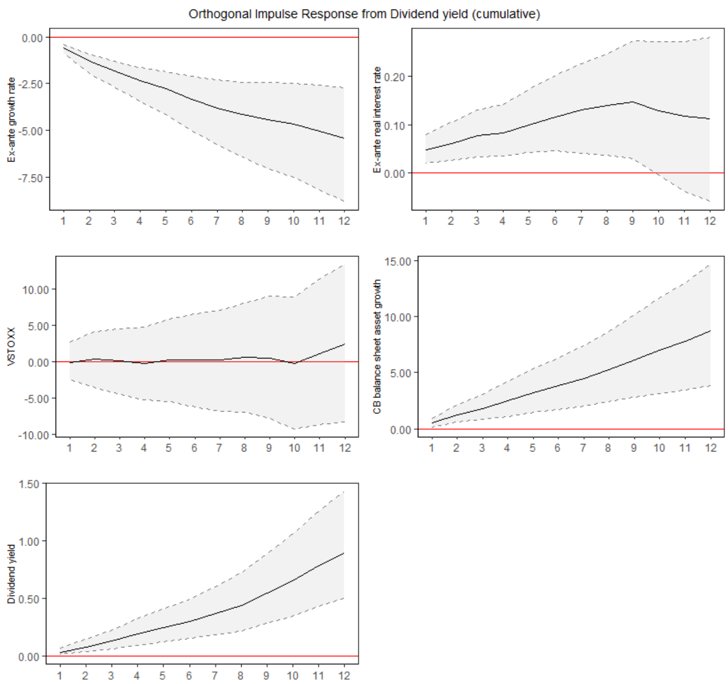
The effect on the implied volatility is mean reverting, but the effects are largely not statistically significant. In cumulative terms, the effects on the implied volatility are negative following the dividend yield shock.



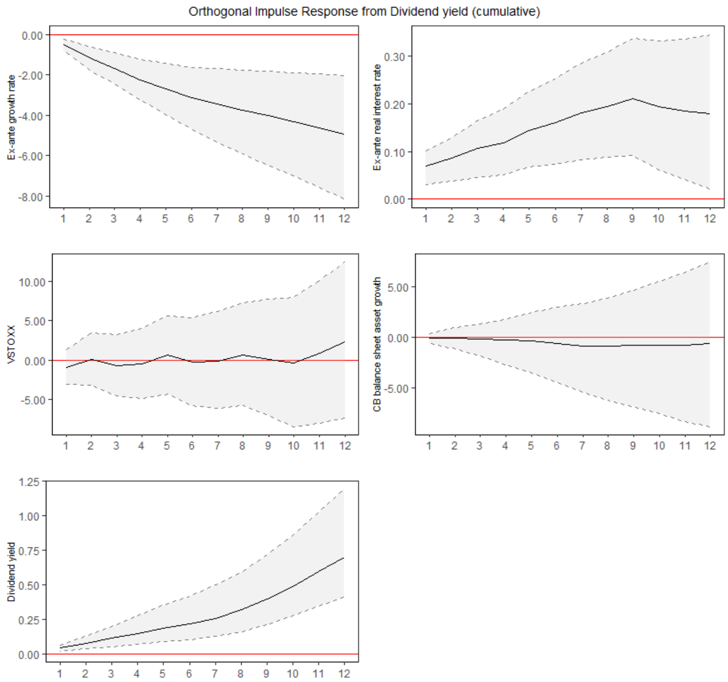
Appendix 1, Figure 7 Impulse response functions for 1000 runs for the euro area VAR model to a shock in dividend yield. 68 % bootstrap confidence interval as shaded area.



Appendix 1, Figure 8 Cumulative impulse response functions for 1000 runs for the euro area VAR model to a shock in dividend yield. 68 % bootstrap confidence interval as shaded area.



Appendix 1, Figure 9 Cumulative impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in dividend yield when central bank balance sheet asset growth is constrained. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.



Appendix 1, Figure 10 Cumulative impulse response functions with 100 draws kept for the euro area structural VAR model to a shock in dividend yield when central bank balance sheet asset growth is unconstrained. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

Appendix 1, Table 1 Forecast error variance decompositions for euro area structural VAR models

Panel A: Shock in *bs*					
Period	*g*	*r*	*VSTOXX*	*bs*	*dy*
1	20.94	6.76	3.72	6.63	10.49
3	20.40	10.14	6.17	7.41	11.17
6	20.25	12.24	7.58	9.73	12.04
9	19.65	12.99	9.97	10.19	12.76
12	18.49	14.49	11.90	10.32	16.06
Panel B: Shock in σ					
Period	*g*	*r*	*VSTOXX*	*bs*	*dy*
1	4.26	2.89	16.24	21.79	7.84
3	4.77	5.59	16.04	21.17	11.52
6	5.69	7.92	15.84	19.76	14.82
9	8.52	8.94	15.31	18.72	14.41
12	9.20	9.85	14.41	18.43	13.18
Panel C: Shock in *dy*. restricted *bs*					
Period	*g*	*r*	*VSTOXX*	*bs*	*dy*
1	22.70	9.02	8.03	8.02	3.79
3	21.74	9.60	8.49	8.83	5.50
6	21.12	12.78	9.74	9.54	7.82
9	20.15	13.22	11.08	10.38	11.12
12	19.51	14.51	13.86	11.03	14.32
Panel D: Shock in *dy*. unrestricted *bs*					
Period	*g*	*r*	*VSTOXX*	*bs*	*dy*
1	22.47	9.16	7.17	4.76	5.38
3	21.13	9.75	8.39	5.32	6.20
6	21.18	12.41	9.25	8.06	7.41
9	19.80	12.32	9.85	9.58	11.38
12	19.62	13.84	13.52	9.92	13.57

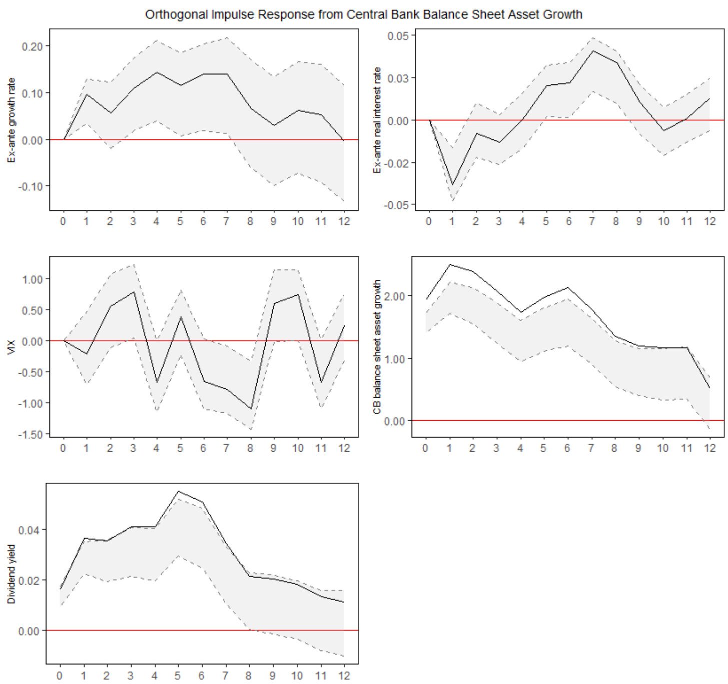
Notes: This table presents the forecast error variance decompositions for different euro area structural VAR models when subject to respective shock indicted in the panel header. Figures are in percentages. See variable definitions from Table 2.

APPENDIX 2 US results from the standard VAR model and additional Tables and Figures

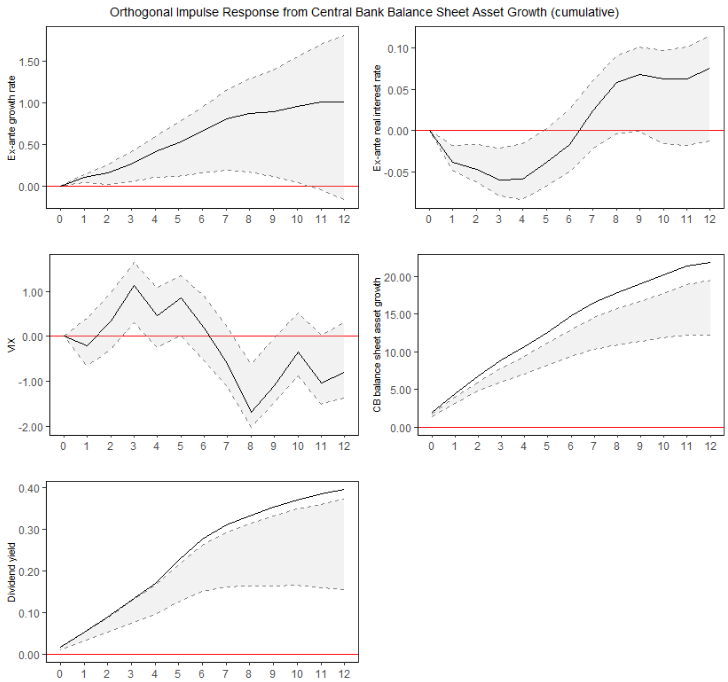
Appendix 2, Figure 1 displays the orthogonal impulse response functions for the US VAR model when the other variables in the model are subject to a shock to the central bank balance sheet asset growth. The impulse responses for the US align better with the expected sign given in Table 4 compared to the euro area. As in the euro area, unconventional monetary policy shock has persistent effects on itself at least for one year ahead.

The ex-ante growth responds positively to the unconventional monetary policy shock and its effect is rather large. The ex-ante real interest rate on the other hand initially declines but the response turns positive after approximately two quarters. After one year, the cumulative effects of the unconventional monetary policy shock are positive for the ex-ante real interest rate but not statistically different from zero.

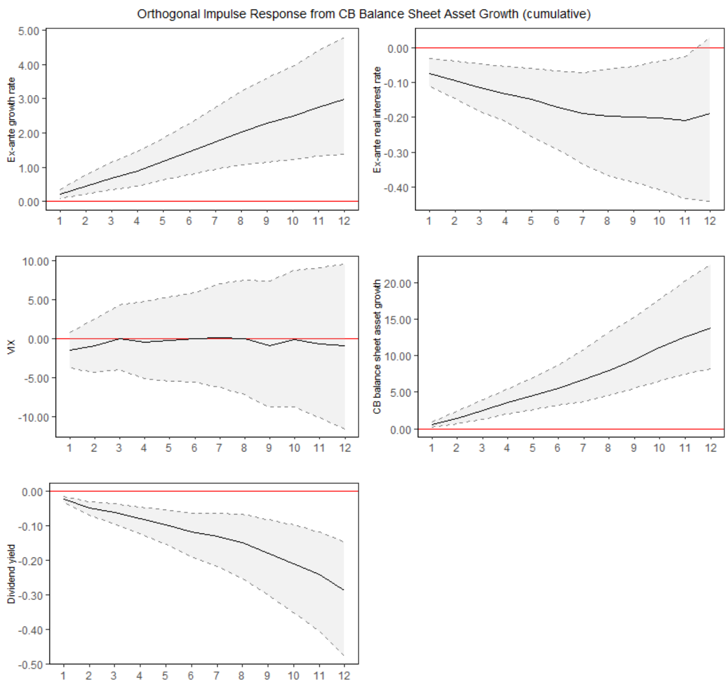
Dividend yield increases after the unconventional monetary policy shock, indicating stock price declines following the shock. The effect is also statistically significant. This is unexpected since, in theory, the dividend yield should decrease, especially given the initially declining ex-ante real interest rate. The implied volatility initially declines but then increases, however most of its effects are not statistically significant.



Appendix 2, Figure 1 Impulse response functions for 1000 runs for the US VAR model to a shock in central bank balance sheet asset growth. 68 % bootstrap confidence interval as shaded area.



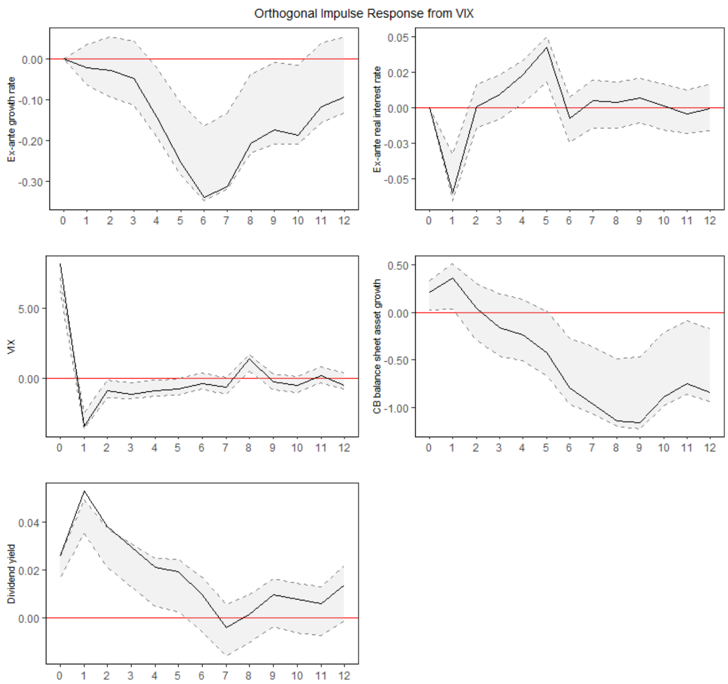
Appendix 2, Figure 2 Cumulative impulse response functions for 1000 runs for the US VAR model to a shock in central bank balance sheet asset growth. 68 % bootstrap confidence interval as shaded area.



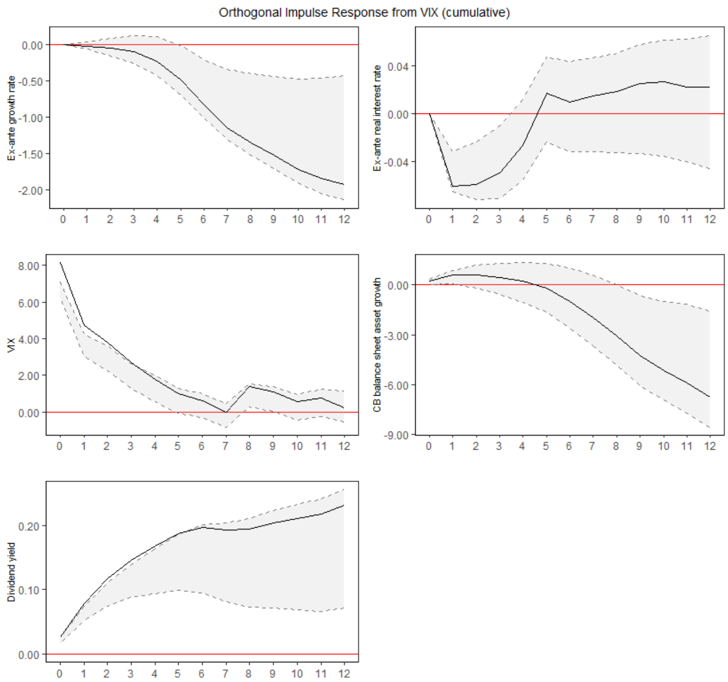
Appendix 2, Figure 3 Cumulative impulse response functions with 100 draws kept for the US structural VAR model to a shock in central bank balance sheet asset growth. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

Appendix 2, Figure 4 shows the orthogonal impulse response functions for the US VAR model when the other variables in the model are subject to a shock to implied volatility. The observed impulse responses align well with the expected signs in Table 4.

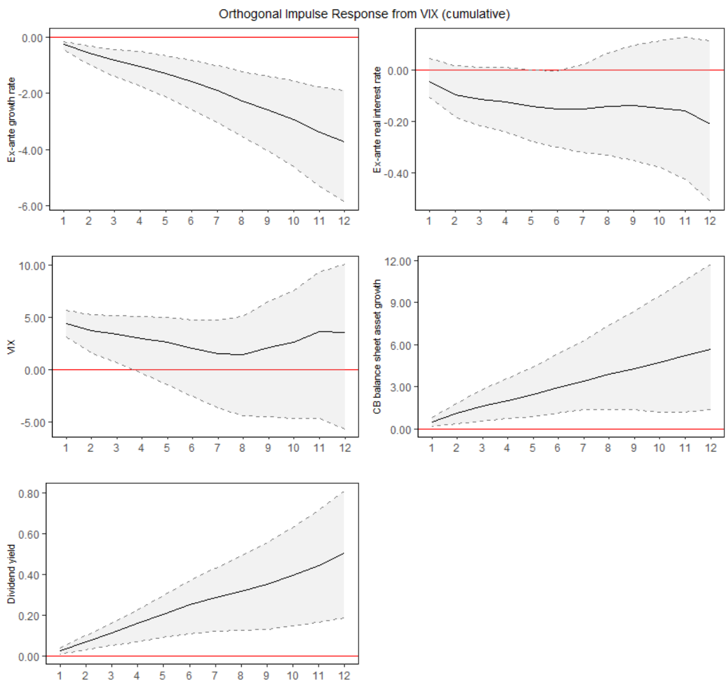
Following the implied volatility shock, the ex-ante growth rate decreases whereas the ex-ante real interest rate initially decreases before eventually turning positive. Overall, the cumulative effect on the ex-ante real interest rate turns negative after five months, however, the effect is not statistically significant. Dividend yield increases after the implied volatility shock, whereas central bank balance sheet asset growth turns negative after three months following an initial positive response. Cumulatively the response of central bank balance sheet asset growth turns negative after six months.



Appendix 2, Figure 4 Impulse response functions for 1000 runs for the US VAR model to a shock in VIX. 68 % bootstrap confidence interval as shaded area.

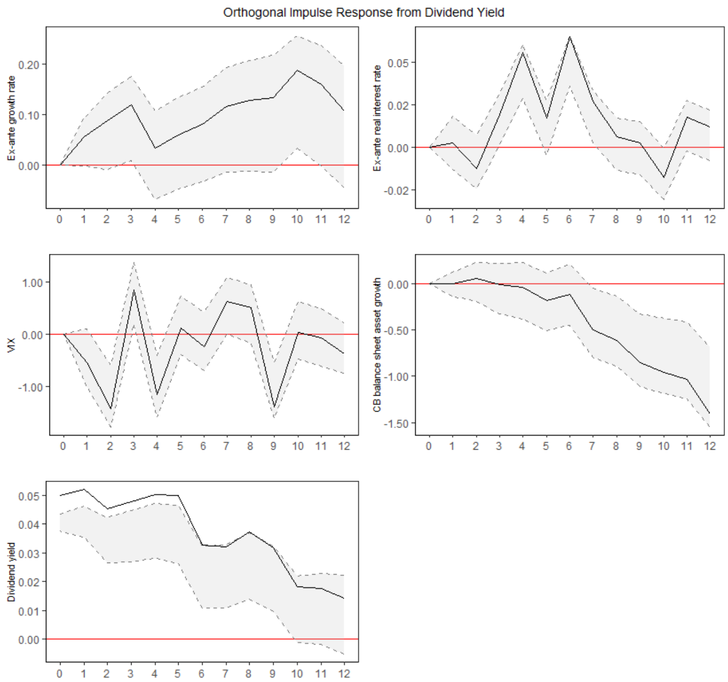


Appendix 2, Figure 5 Cumulative impulse response functions for 1000 runs for the US VAR model to a shock in VIX. 68 % bootstrap confidence interval as shaded area.

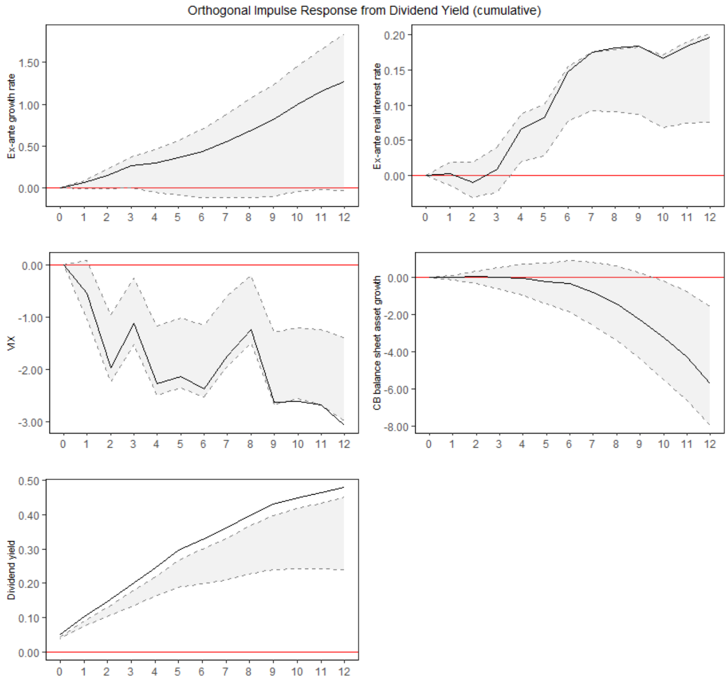


Appendix 2, Figure 6 Cumulative impulse response functions with 100 draws kept for the US structural VAR model to a shock in VIX. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

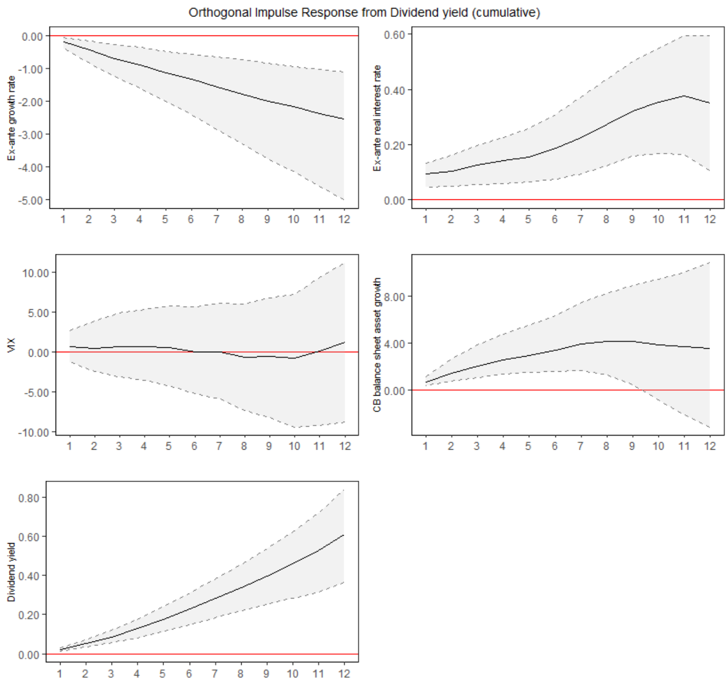
Appendix 2, Figure 7 shows the orthogonal impulse response functions for the US VAR model when the other variables in the model are subject to a shock to the dividend yield. Similar to the euro area, the initial dividend yield shock causes a persistent effect on itself. Surprisingly, the ex-ante growth rate is positive for the whole one-year ahead period contrary to the expected signs in Table 4 but its effects are not statistically significant. Overall, the ex-ante real interest rate increases following the shock even though there are some periods when its growth is negative. The implied volatility again exhibits mean reverting behavior, with a negative cumulative effect. The central bank balance sheet asset growth shows no changes following the dividend yield shock for six months, but turns negative after seven months, indicating quantitative tightening similar to the euro area.



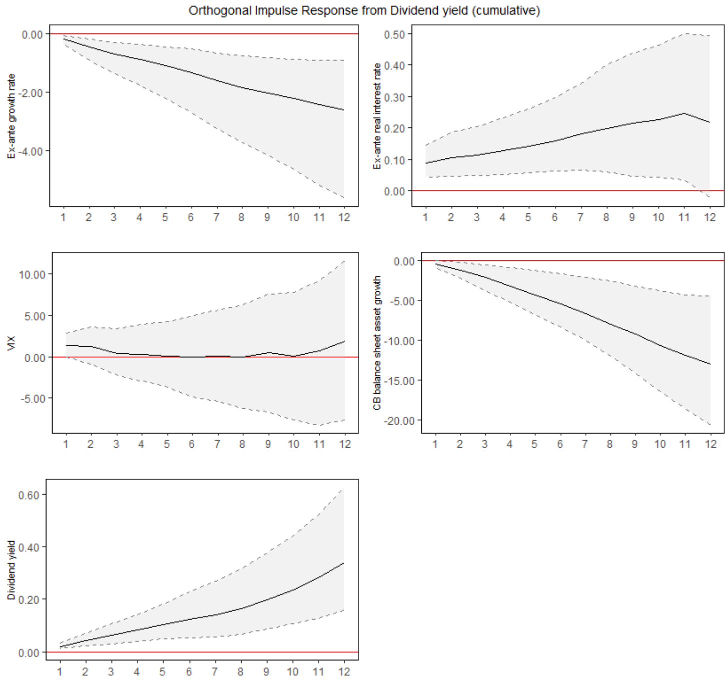
Appendix 2, Figure 7 Impulse response functions for 1000 runs for the US VAR model to a shock in dividend yield. 68 % bootstrap confidence interval as shaded area.



Appendix 2, Figure 8 Cumulative impulse response functions for 1000 runs for the US VAR model to a shock in dividend yield. 68 % bootstrap confidence interval as shaded area.



Appendix 2, Figure 9 Cumulative impulse response functions with 100 draws kept for the US structural VAR model to a shock in dividend yield when central bank balance sheet asset growth is constrained. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.



Appendix 2, Figure 10 Cumulative impulse response functions with 100 draws kept for the US structural VAR model to a shock in dividend yield when central bank balance sheet asset growth is unconstrained. The solid line indicates the median value and the dashed lines the 16 % and 84 % error bands.

Appendix 2, Table 1 Forecast error variance decompositions for the US structural VAR models

Panel A: Shock in *bs*					
Period	*g*	*r*	*VIX*	*bs*	*dy*
1	10.09	8.14	7.66	6.45	14.52
3	10.61	9.10	7.74	8.51	14.61
6	11.06	10.16	8.48	9.44	14.08
9	11.17	11.44	10.19	11.29	14.44
12	11.41	12.95	10.89	12.09	14.09
Panel B: Shock in σ					
Period	*g*	*r*	*VIX*	*bs*	*dy*
1	12.02	9.30	23.42	5.10	10.76
3	12.37	11.40	21.62	7.02	13.34
6	12.14	11.11	20.96	7.41	12.88
9	12.98	11.59	19.69	7.82	12.78
12	12.70	12.30	18.86	8.91	13.95
Panel C: Shock in *dy*. restricted *bs*					
Period	*g*	*r*	*VIX*	*bs*	*dy*
1	7.40	12.07	4.55	14.87	8.66
3	7.96	11.44	5.17	15.25	11.34
6	8.52	12.16	5.71	15.31	13.14
9	8.67	12.60	7.26	15.10	13.59
12	8.71	13.28	9.45	13.88	13.92
Panel D: Shock in *dy*. unrestricted *bs*					
Period	*g*	*r*	*VIX*	*bs*	*dy*
1	7.37	8.02	6.42	5.52	18.29
3	8.21	8.08	7.13	6.65	14.78
6	8.94	9.72	7.76	6.97	13.74
9	9.82	10.64	8.61	9.58	13.72
12	9.74	11.25	9.76	10.77	13.88

Notes: This table presents the forecast error variance decompositions for the different US structural VAR models when subject to respective shock indicted in the panel header. Figures are in percentages. See variable definitions from Table 2.

APPENDIX 3 Use of AI Based Tools

In this thesis I have used AI-based tools to optimize and improve different section and sentences in this thesis. Specifically, I have used OpenAI's ChatGPT AI tool. When asked from ChatGPT how I have used it in this thesis it provided following answer. "Based on our previous interactions, it appears that you have used my help to optimize and improve various paragraphs and sentences in your thesis. Specifically, you have asked me to rephrase and optimize certain sections to improve clarity, conciseness, and overall effectiveness in communicating your ideas. Overall, it seems that you have utilized my help to refine and enhance your writing."

Additionally, the ChatGPT has been used to create policy recommendations based on the results gathered in this thesis. These policy suggestions have been filtered and checked for the correctness by the author. These policy recommendations are located in the final two paragraph of section 1.1.