UNIVERSITY OF TURKU
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How euro area's monetary policy effects differ among its countries

Including findings about Finland

Department of Economics
Master's thesis

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Significance of the common monetary policy of the euro area is emphasized especially in times of crises. It is one of the most important tools for price stabilization. The aim of this thesis is to study how monetary policy effects differ among euro countries, and how Finland is positioned in such classification. This thesis explores how the real economy variables such as output and employment react in different countries. Special attention is paid to the government bonds.

Such questions are usually studied by different variants of vector autoregressions (VAR). This research follows the methodology of Altavilla et al. (2019) and Gertler & Karadi (2015), which is based on VAR and monetary policy surprises. Surprises are identified from the sudden price movements of selected bonds and indices during the European Central Bank's (ECB) press releases and conferences. Data sources are the EA-MPD database supported by ECB, and daily time series of selected countries' sovereign bonds. Effects of the monetary policy surprises on the bond yields and term premia are studied. Results show that such effects are persistent and quite homogenic among countries. As expected, bonds of stronger economy countries, such as Germany and France, behave most predictably. Finland is positioned closely to these countries in most cases. Term premium is found to be dependent on the bond yield level.

As a conclusion, the euro area countries' economies react to the monetary policy measures in a similar way, although some differences can be detected from time to time. Same holds for the government bonds, which can be classified according to the country-specific risk as more and less predictable. Business cycles synchronization has grown, but it usually decreases in crisis times and increases during periods of economic growth. This can be considered as a positive outcome in terms of the monetary policy efficiency.

Key words: monetary policy, VAR, bond, European Central Bank, euro area.

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Euroalueen yhteisen rahapolitiikan merkitys korostuu erityisesti kriisien aikana. Tämä on yksi tärkeimmistä keinoista hintatason vakauttamiseen. Tutkielman tarkoitus on selvittää, miten rahapolitiikan vaikutus eroaa maiden välillä, ja mihin Suomi sijoittuu sellaisessa tarkastelussa. Tutkielmassa kartoitetaan, miten reaalimuuttujat, kuten tuotanto ja työllisyys, reagoivat eri maissa. Huomiota kiinnitetään myös valtioiden velkakirjoihin.

Sellaisia kysymyksiä tutkitaan yleensä erilaisilla vektoriautoregression (VAR) variaatioilla. Tämä tutkielma seuraa Altavillan ym. (2019) ja Gertlerin & Karadin (2015) metodologiaa, joka perustuu VAR-analyysiin ja rahapolitiikan yllätyksiin. Yllätyksiä identifioidaan tiettyjen velkakirjojen hintojen ja indeksien äkillisistä muutoksista Euroopan keskuspankin (EKP) tiedotustilaisuuksien aikana. Aineistona on EKP:n ylläpitämä EA-MPD-tietokanta, ja lisäksi valittujen valtioiden velkakirjojen tuottojen päivittäiset aikasarjat. Tutkitaan rahapolitiikan yllätysten vaikutuksia velkakirjojen tuottoihin ja myös niiden juoksuaikapreemioihin. Tulokset osoittavat, että yllätysten vaikutus velkakirjojen tuottoihin on pitkään kestävä ja melko homogeeninen maiden välillä. Odotetusti vahvempien talouksien, kuten Saksan ja Ranskan, velkakirjat käyttäytyvät ennalta arvattavammin. Suomi sijoittuu edellä mainittujen maiden lähelle. Juoksuaikapreemio osoittautuu riippuvan tuoton tasosta.

Johtopäätöksenä voidaan todeta, että euromaiden taloudet reagoivat rahapolitiikan toimenpiteisin melko samantyyppisesti, vaikka eroavaisuuksia myös havaitaan jonkin verran. Sama pätee myös valtioiden velkakirjoihin, jotka voidaan luokitella maakohtaisen riskin mukaan enemmän ja vähemmän ennustettaviin. Suhdanteiden synkronointi on kasvanut, mutta se yleensä heikkenee kriisien aikana ja vahvistuu noususuhdanteissa. Sitä täytyy pitää positiivisena asiana rahapolitiikan tehokkuuden näkökulmasta.

Avainsanat: rahapolitiikka, VAR, velkakirja, Euroopan keskuspankki, euroalue

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Abbreviations

CPI Consumer Price Index

EA-MPD Euro Area Monetary Policy Event-Study Database

ECB European Central Bank

ELB Effective Lower Bound

EONIA Euro Overnight Index Average

EU European Union

FAVAR Factor Augmented Vector Autoregression

FG Forward Guidance

GDP Gross Domestic Product

GVAR Global Vector Autoregression

HHI Herfindahl–Hirschman Index

HICP Harmonized Index of Consumer Prices

IJC Initial Jobless Claims

ILS Inflation-Linked Swap

IRF Impulse Response Function

IS Investment–Saving

IV Instrumental Variable

LM Liquidity preference - Money supply

LS Least Squares

MRO Main Refinancing Operations

OIS Overnight Index Swap

OLS Ordinary Least Squares

QE Quantitative Easing

SVAR Structural Vector Autoregression

VAR Vector Autoregression

1 Introduction

In the modern unstable world, monetary policy can be considered as a force opposing chaos and striving to steadiness and stability. Crises happen one after another, governments come and go (in democratic countries), politics turn from left to right and back, but the central bank is always there to bring some order and belief in the future. At least in theory.

In practice, central banks are trying to stabilize prices and guide the economic activity through the monetary policy measures. This is especially difficult in case of the euro area, which consists of 20 different countries. Inevitably effects of the monetary policy actions must differ. This question has been studied from the time of the introduction of the euro by Angeloni et al. (2003), Barigozzi et al. (2014) and Corsetti et al. (2022) to name a few. Research methods have also been developing considerably starting from basic vector autoregressions (VARs) and structural VARs in early papers (Peersman & Smets 2001) to the sophisticated multi-level approaches such as in Burriel and Galesi (2018) and Burgard et al. (2019).

The aim of this research is to gather a recent knowledge about how effects of ECB's monetary policy actions differ among eurozone countries, with additional focus on Finland. Do their economies and business cycles converge? Also, this thesis is trying to answer the following supplementary research questions:

- What kind of policy produces most different effects among selected countries?
- How is Finland positioned among other countries in terms of monetary policy effects?

Apart from the literature review, I perform an econometric study following the procedure of Altavilla et al. (2019), but with newer and expanded data, including time series of Finnish government bonds. The methodology is based on the monetary policy surprises identification technique first published by Gürkaynak et al. (2005) and VAR with the external instrument identification (Stock & Watson 2012, Mertens & Ravn 2013, Gertler & Karadi 2015). The main data source is the EA-MPD public database of monetary policy surprises, available from the European Central Bank's website. Additional time series have been obtained from the LSEG Workspace (formerly Refinitiv).

Results of this research are encouraging. Economies of the euro area countries mostly react to monetary policy measures consistently. There is evidence that monetary policy succeeds not only in short-term interest rate measures, but also in forward guidance measures, affecting long-term interest rates. There are also reports that stronger economies such as Germany and France benefit from monetary policy measures more and behave more predictably. This is the case especially for longer term measures, such as quantitative easing. Finnish economy, although not without its problems, is situated in the group of benefitting the most.

Structure of this thesis is the following. In chapter 2 the theoretical background of monetary policy measures is briefly presented. In chapter 3 I go through the econometrical methodology including the monetary policy surprises identification and their usage, along with the most relevant recent literature. In chapter 4 I present the results from my econometrical research together with some interpretation of them. The last chapter contains the summary of literature's and empirical section's results.

2 Theoretical background

2.1 Brief history of the monetary policy

Since ancient times the issue of money was a privilege of rulers, and a coin's value was based on the precious metal's value, of which it was made of, especially of gold and silver. However, already in Roman empire many cases of inflation were documented. The reason for that was issuing more money than were precious metals available, so, for example, silver percentage in coins became sometimes as low as 4 percent. (Davies 2013.)

Precious metals continued to play a crucial role in determining the value of money until 20th century. Different forms of paper money were introduced during that time, but usually the bill's value was tied to the certain amount of a precious metal. Governments could take liberties with printing as many bills as they needed, which often resulted into a severe inflation and hyperinflation. Also, first central (regional) banks were established at the late Middle Ages, but their functions were quite far from the modern central banks' operations. (Davies 2013.)

Modern monetary policy era can be considered begun with the end of the Bretton Woods system in 1971, when US dollar's tie to gold was severed. From then on, money lost any connection to precious metals and became only subject to the central bank's control (although, most central banks still keep gold reserves). Developed countries' central banks are independent entities which do not report directly to the government, but follow their own targets stated in the constitution, such as stable price level, currency value, economic growth etc. (Blanchard et al. 2010.)

To achieve their targets, a number of approaches can be taken. ECB and the Fed strive to keep a certain inflation level (inflation targeting). Another approach, popular in the past, was to target the money supply. Currency's exchange rate can be also controlled, especially in case of a fixed rate. For that, the central bank performs its actions, which may or may not be announced in advance.

Effects of individual monetary policy actions have caused much debate historically. Assessment of such effects is not trivial, and different approaches can result in different outcomes. Consensus in empirical literature is that real economy's variables' response to monetary policy actions is hump shaped. A peak is achieved within a period from several months to two years, and then the response gradually goes to zero. (Walsh 2017.)

2.2 Theory behind monetary policy effects

In this chapter I go through how monetary policy measures transmit to the real economy and how their effects could be detected and quantitatively estimated.

2.2.1 Monetary policy transmission

According to Mishkin (1995), monetary policy affects the real economy through several channels: interest rate, exchange rate, asset prices and credit channel. Interest rate channel is the most direct of these, as it affects short term interests almost immediately. Due to nominal rigidities, long term interest rates are also affected. Changes in these interest rates are in focus of the empirical part of this thesis. Interest rate's effect mechanism is presented in figure 1.

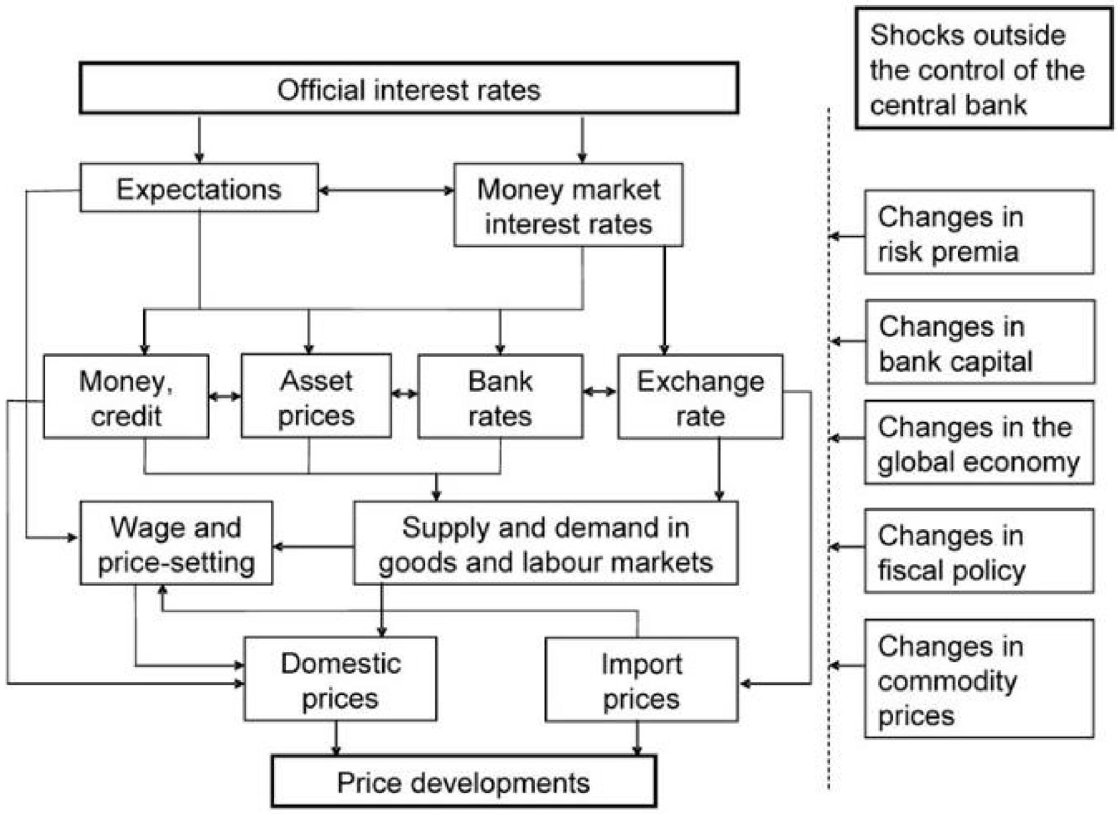

Figure 1 Interest rate channel and its effects. Picture: ECB website

As a general rule, lower interest rate decreases the cost of capital, which stimulates the economic activity. This policy type is called expansionary. Change in the opposite direction is a part of the contractionary monetary policy.

However, when interest rates are near effective lower bound (ELB), which may or may not equal zero, central bank' main instrument loses its efficiency. This situation is known as a liquidity trap. Then central bank must recourse to alternative instruments such as open-market operations, which are described in the next chapter.

Credit channel of the monetary policy transmission can be seen as an amplifier for interest rate channel, that is, it enhances the effect of interest rate changes on the cost of capital for firms through external finance premium (additional cost of raising funds from outside). Contractionary monetary policy typically decreases balance sheet's value, which in turn weakens the borrower's financial position and increases the risk premium that lender charges from the borrower. (Bernanke & Gertler 1995)

Asset price channel manifests itself in the dependence of the stock and bond prices on the money supply, which is affected by the monetary policy. In general, a decrease in money supply leads to a decrease in the asset prices, and vice versa. (Mishkin 1995.)

Exchange rate channel is important for countries with a lot of trade involving a foreign currency. Contractionary monetary policy leads to an increase in the domestic currency rate and through that a decrease in the output. (Mishkin 1995.)

2.2.2 Central bank's monetary policy instruments

Developed countries' central banks state a stable and low inflation (around 2% yearly), and also a stable currency's exchange rate as their main targets. In addition, other targets can be pursued, such as low unemployment level and economic growth. The main aim of ECB's actions is stable price level and value of the euro (ECB 2025).

ECB, as many other central banks, employs the short term (deposit facility) interest rate as its main instrument. This, as long as related communication, affects banking interest rates and through this the real economy. (ECB 2025.)

Following other types of monetary policy actions can also be observed, especially when short term interest rate is already near ELB and cannot be used:

Forward guidance - promise to keep deposit facility interest rate at the certain (low) level for some time. This increases the expected inflation and thus potentially stimulates economic activity. (Romer 2019.)

Open market operations - central bank buys (sells) assets of a certain type from the open market. One especially important variation of this type is quantitative easing (QE), when the central bank buys long-term sovereign bonds and short-term private bonds. This results in some decrease in long-term interest rates and conversely increases private consumption and overall economic activity. (Walsh 2017.)

There are also a few other methods such as credit guidance, helicopter money etc. that are less relevant for this thesis and thus omitted.

2.2.3 New Keynesian macroeconomic model

To study and explain any policy measures' effects on the real economy, mathematical models are widely utilized. Some early macroeconomic models are money-neutral, that is, monetary policy in these does not exist. For this to be the case, there should be no economic frictions, prices and wages should adapt immediately and so on. This obviously does not hold in any real-world economy.

On the other end of the spectrum, central banks use very sophisticated models of the economy to design and access an impact of their actions, and introduction of such models does not serve the purpose of this thesis. Instead, here are presented the foundations of a simple New Keynesian model, which link nominal variables such as interest rate to the real economy's variables starting from consumption and investment. (Jarociński & Karadi 2020.)

As stated before, let us assume that central bank's main goal is stable inflation close to 2% level and it assigns nominal interest rate by the Taylor rule (Jarociński & Karadi 2020):

$$i_t = \kappa_\pi \pi_t + \kappa_x x_t + \varepsilon_t,$$

where $\kappa_{\pi,t}$ are parameters, π_t inflation, and x_t measure of economic slack (deviation from the steady state cost of the intermediate good).

Because of the nominal rigidities, short term as well as long term bond rates are affected by the nominal interest rate (loglinear approximation) (Karadi & Gertler 2015):

$$i_t^m = E_t \frac{1}{m} \left(\sum_{j=0}^{m-1} i_{t+j} \right) + \phi_t^m, \tag{1}$$

where E_t means expected value, i_t^m is the annual bond yield, and ϕ_t^m is the term premium.

This formula is derived from the basic interest rate calculations: long term normalized (per short term, usually a year) rate is a sum of the short term compounded rates divided by short terms amount. Term premium is a compensation for a risk involved in keeping funds invested into the bond for a longer period. Set of interest rates thus calculated is called a yield curve (Romer 2019.)

Monetary policy-related changes in the interest rates are thus transmitted into the bond rates through the yield curve and potentially also the term premium. In the simplest form term premium should be a local constant in the steady state of this model, depending only on country-specific risks involved for holding bonds for longer times. However, risk premium might not depend only on (rational) risk-related consumption preferences of the investor. As is shown in the chapter 2.2.6, monetary policy measures can affect it also directly, if it depends on the absolute level of the interest rate. (Karadi & Gertler 2015.)

The real rate (r_t) is determined by the Fisher equation (approximation):

$$i_t = r_t + E_t \pi_{t+1},$$

where π_{t+1} is the next period's expected inflation.

The central bank can influence also the expected inflation by communication measures, as can be seen in the empirical section of this thesis. This can be interpreted as though the central bank has some information about the upcoming disturbances in the economy and thus warning the economic agents (Jarociński & Karadi 2020)

The real interest rate affects consumption through some form of intertemporal consumption preferences, that is, increase in the real rate reduces the current consumption in favour of the future one (Jarociński & Karadi 2020).

The real interest rate affects also the investment such as in the formula:

$$Q_t = 1 + \mathrm{f}\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}}\mathrm{f}'\left(\frac{I_t}{I_{t-1}}\right) - \mathrm{E_t}\Lambda_{\mathrm{t,t+1}}\left(\frac{I_{t+1}}{I_t}\right)^2 \mathrm{f}'\left(\frac{I_{t+1}}{I_t}\right),$$

where Q_t is value of capital, $\Lambda_{t,t+1}$ stochastic discount factor, I investment, f investment adjustment cost function.

It can be shown that when the real rate increases, the capital value decreases, so the investment also decreases, as it can also be seen in a textbook IS-LM model (Jarociński & Karadi 2020). Hence these dependencies form the basis of the monetary policy transmission mechanism in this model.

Overall, from this relatively simple model we can determine if not the scale, then at least the directions (signs) of monetary policy effects on the real economy variables. It makes sense to measure a magnitude of such effects econometrically, as is described in the following chapters.

2.2.4 Alternative theories

Monetarism offers a different approach to the monetary policy's theoretical foundation. Friedman (1960) argues that inflation depends directly on a money supply, so it is money supply that should be targeted by the central bank, that is, it should be grown yearly according to GDP's growth. Monetarism enjoyed some popularity in 1970-1980s, which declined since then.

Apart from mainstream macroeconomics, other schools of thought continue to exist and to get some recognition, such as Austrian business cycle theory.

2.2.5 Country - specific effects

In the euro area, there is only one implementor of monetary policy - the European Central Bank (ECB). Although integrated to a high degree, EU countries are still independent nations and have their own governments, financial policies and economy structures, which could differ significantly. Also, countries could be in different stage of a business cycle, so that the contractionary monetary policy can curb the excess growth in one country, but at the same time further deepen other country's depression.

Inflation levels may vary across the euro zone countries, as well as their economy fundamentals, such as production and services sectors' size, productivity, share of high-tech and primary sector, wages, price rigidity etc. These factors, as long as potentially different consumption preferences, provide reasons for differences in the monetary policy transmission and make a theoretical assessment of monetary policy measures difficult. Even in the simple Keynesian model there are country-specific parameters: initial capital amount and investment adjustment cost function.

In addition to that, Ciccarelli et al. (2013) emphasize the importance of credit channel transmission in cross-country differences. Depending on the state of the economy, external finance premium may vary, which amplifies interest rate changes accordingly.

Some properties of the ECB are designed to address these problems. As an entity, ECB is independent of countries' governments. In addition to executive board, ECB's Governing Council consists of representatives of all euro zone's national central banks. All the key monetary policy decisions are made by the Governing Council by the rotating voting principle, so at least in theory, no country can dictate the euro area's monetary policy. (ECB 2025.)

This view, however, is challenged by Moschella and Diodati (2020). They used statistical analysis of the heads of the national central banks' public speeches to identify on what topics they disagreed with the general line of the ECB. The authors have found that membership in a political party and the national government's ideology significantly correlate with these disagreements.

2.2.6 Sovereign bond rates

Sovereign bonds' trading rates are dependent on their nominal yield, term and current interest rate (same for the euro area). So, for example, when the interest rate increases, government bonds' rates decrease, and vice versa.

Also, investing in government bonds involves country-specific risks, which are different for the euro area countries. According to Manganelli and Wolswijk (2009), spreads among euro area's government bond rates are affected by liquidity and credit risk, as shown in expression:

$$\mathrm{P_t^i} = \underbrace{\mathrm{E_t(m_{t+1})E_t\left(d_{t+1}^i + P_{t+1}^i\right)}}_{\text{expected payoff}} + \underbrace{cov_t\left(m_{t+1}, d_{t+1}^i\right)}_{\text{credit risk premium}} + \underbrace{cov_t\left(m_{t+1}, P_{t+1}^i\right)}_{\text{liquidity risk premium}},$$

where P_t^i is the bond rate at the moment t, m_{t+1} investor's marginal rate of consumption substitution between moments t and $t+1$, and d^i_{t+1} coupon payment.

Monetary policy measures affect risk premia in several ways. One of them is through incentives to take risks depending on the interest rate level. When such rate is low, incentive to take risk grows, because the certain absolute value of return on investment can be achieved with riskier assets. Inversely, when the rate is high, such return is achieved with less risky assets. Risk level is related to the state of country in question's economy. Hence overall risk premium also depends on the interest rate level directly. (Manganelli & Wolswijk 2009.)

This pattern is confirmed by several studies of the euro zone, including Codogno et al. (2003). According to them, yield spread is significantly affected by international risk factors as well as debt-to-GDP ratio. Bernoth et al. (2012) find that liquidity risk in the euro zone is insignificant.

Term premium's response to the monetary policy measures in the euro area is covered in the empirical section.

2.3 Monetary policy surprises

One of the ways to make monetary policy efficient is to make it surprising. Even common sense can explain this - if some change is expected, it is probably already counted into asset prices. But if it is not, markets react immediately according to the interest rate and risk pattern described in the previous chapter. This can be seen in high-frequency quote data in the moments of policy changes announcements and related press conferences. Gertler and Karadi (2015) studied effects of such monetary policy surprises on government bonds, and through them on output and inflation. Their results show that surprises affect credit costs significantly, and through that sovereign bond's yield curve and conversely output.

Gertler and Karadi (2015) also found that the term premium (expression 1) reacts strongly to the monetary policy surprises, sometimes explaining all the bond rate reaction. According to the basic New Keynesian model, term premium should remain constant, and all the monetary policy transmission should happen via the yield curve. In this respect such model is insufficient, because it does not take into account the risk factors associated with absolute interest rate level among other things.

Surprises can also be classified depending on their nature and outcome. Central bank's communication is important for determining long-term interest rates (forward guidance) and can be considered as a property of a surprise. Andrade and Ferroni (2021) apply the principal component analysis to the high-frequency rate data deviations and identify two types of monetary shocks coming from the monetary policy surprises: Delphic and Odyssean. Delphic shock is about the central bank's oracle-like reaction to a new macroeconomic information within its policy rule, and Odyssean is about the central bank's commitment to deviate from that rule in the future (tying its hands to the mast). The authors show that stock markets and future interest rates react to these shocks in an opposite way. Altavilla et al. (2019) confirm this classification with their findings too (figure 2).

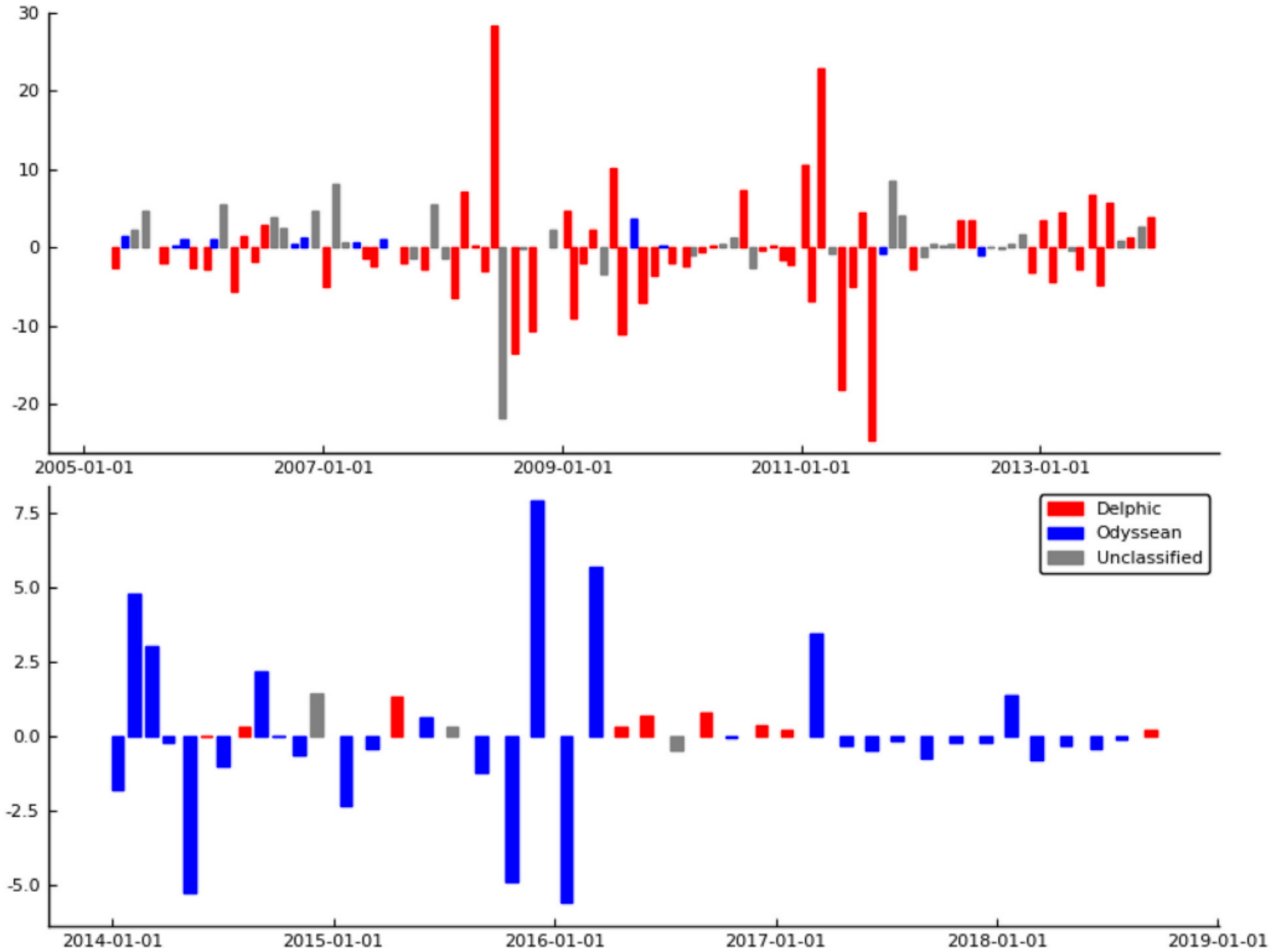

Figure 2 Delphic and Odyssean surprises from ECB. Picture: Altavilla et al. (2019), CC BY 4.0

Classification of monetary policy surprises is crucial for the measurement of their effects. These subjects are in the focus of the empirical part of this thesis.

3 Literature review

In this chapter I briefly describe the most relevant econometrical methodologies that have been used in the literature and in the empirical section, as well as selected results related to the monetary policy transmission in different countries.

3.1 Measurement methodology

Measurement of monetary policy effects is not a trivial task. They are difficult to isolate from other economic disturbances such as financial policy changes, trade balance changes, world economy shocks etc. But there are methods that have proved to be working, which are based on the time series concept. Economic variables are measured at regular intervals, and resulting time series can be studied statistically. In the following chapters I cover the most relevant statistical methods for this thesis.

3.1.1 Vector autoregressions (VAR)

VARs provide a relatively easy to implement framework for monetary policy measures, which does not necessary require much of a theoretical foundation. Policy measures are considered as shocks to economic variables, and then reactions to shocks can be studied as impulse response functions (IRF) from the variables' time series. It has been used in different forms for several decades and proved to be useful for the data description and forecasting. (Stock & Watson 2001.)

Multivariate time series consist of economic variables, which are measured at regular moments of time (daily, weekly, yearly, etc). For VAR to be applicable, time series must satisfy some requirements, the most important of which is autocorrelation. Autocorrelation means that every variable's value at any given measurement time is correlated to its and other variables' values at this and previous measurement times. In other words, they depend on their common history, which is a very valid assumption for economic variables.

Basic, or reduced-form VAR model is shown in expression:

$$y_t = \nu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t,$$

where y_t is a vector of variables at the moment of time t $(t\text{-}1,\ ..\ t\text{-}p)$, p number of lags, v constant term, $A_1 ... A_p$ interdependence matrices, u_t correlated error term with covariance matrix Σ_u.

This can be rewritten in the compact form:

$$y_t = [\nu, A_1, \dots, A_p] Z_{t-1} + u_t,$$

where Z_{t-1} is a long vector containing $y_{t-1} \dots y_{t-p}$: $(1, y'_{t-1} \dots y'_{t-p})'$. Matrices $A_1 \dots A_p$ as well as covariance matrix Σ_u can be estimated from the data by least squares:

$$\hat{A} = [\hat{\nu}, \widehat{A_1}, \dots, \widehat{A_p}] = \left(\sum_{t=1}^{T} y_t Z'_{t-1}\right)\left(\sum_{t=1}^{T} Z_{t-1} Z'_{t-1}\right)^{-1} = YZ'(ZZ')^{-1},$$

$$\widehat{\Sigma_u} = \frac{\hat{U}\widehat{U'}}{T - K_p - 1}$$

where $\hat{U} = Y - \hat{A}Z$ are the LS residuals, K is a dimension of a variable vector, T sample size (Kilian & Lütkepohl 2017).

Resulting statistical model can be used, for example, for forecasting.

3.1.2 Structural VAR

Applying basic VAR directly to economic time series seldom produce credible and usable results, apart from school examples. If applied only to a limited number of variables, there is in the end too little information used. Also, impulse response functions (IRF) with the basic reduced-form VAR can only be used if shocks are considered to be independent. This assumption is not plausible in economics, economic shocks always occur to several (but not all) variables simultaneously.

To address that, the structural VAR can be applied. The idea behind it is that economic shocks must have some structure, that can be recovered from the reduced-form VAR. Structure can be expressed as matrix and the stochastic part can then be considered as uncorrelated white noise, as per expression 2:

$$B_0 y_t = B_1 y_{t-1} + \dots + B_p y_{t-p} + w_t, \Rightarrow$$

$$y_t = \underbrace{B_0^{-1} B_1}_{A_1} y_{t-1} + \dots + \underbrace{B_0^{-1} B_p}_{A_p} y_{t-p} + \underbrace{B_0^{-1} w_t}_{u_t}, \qquad (2)$$

where covariance matrix $\Sigma_w = I_K$ (white noise), and $\Sigma_u = B_0^{-1} B_0^{-1\prime}$.

Estimation of the B_0^{-1} matrix is called shocks identification. To identify them purely from the sample data, additional assumptions are needed. Amount of literature about identification methods is vast, starting from simplest forms such as Cholesky (recursive) identification (Kilian & Lütkepohl 2017). In this thesis, identification with the external instrument has been used, and it is covered in the next chapter.

In economics, estimated matrices themselves are of little interest. Instead, impulse response functions (IRF) provide an intuitively understandable way of estimating effects of the shocks. Impulse response means a change in the variable vector y_t caused by one-time shock in w_t. Once the model is estimated and shocks identified, IRF can be calculated from formulas:

$$\frac{\partial y_{t+i}}{\partial w_t'} = \Theta_i, \mathrm{i} = 0,1, \dots H,$$

where H is a maximum time horizon and Θ_i is a K x K matrix, consisting of elements:

$$\theta_{jk,i} = \frac{\partial y_{j,t+i}}{\partial w_{kt}}$$

For the IRF analysis, the stationarity requirement can be relieved, that is, it can be applied to integrated time series directly (Kilian & Lütkepohl 2017).

IRF are often reported as graphs, where the time period after which the effect subsides to zero (or half) can be seen, as in figure 3. It can also be shown, that due to the linearity of VAR, impulse responses are symmetric to the sign of the shock, and linearly scalable to the magnitude. This makes IRF graphs easy to interpret. (Kilian & Lütkepohl 2017)

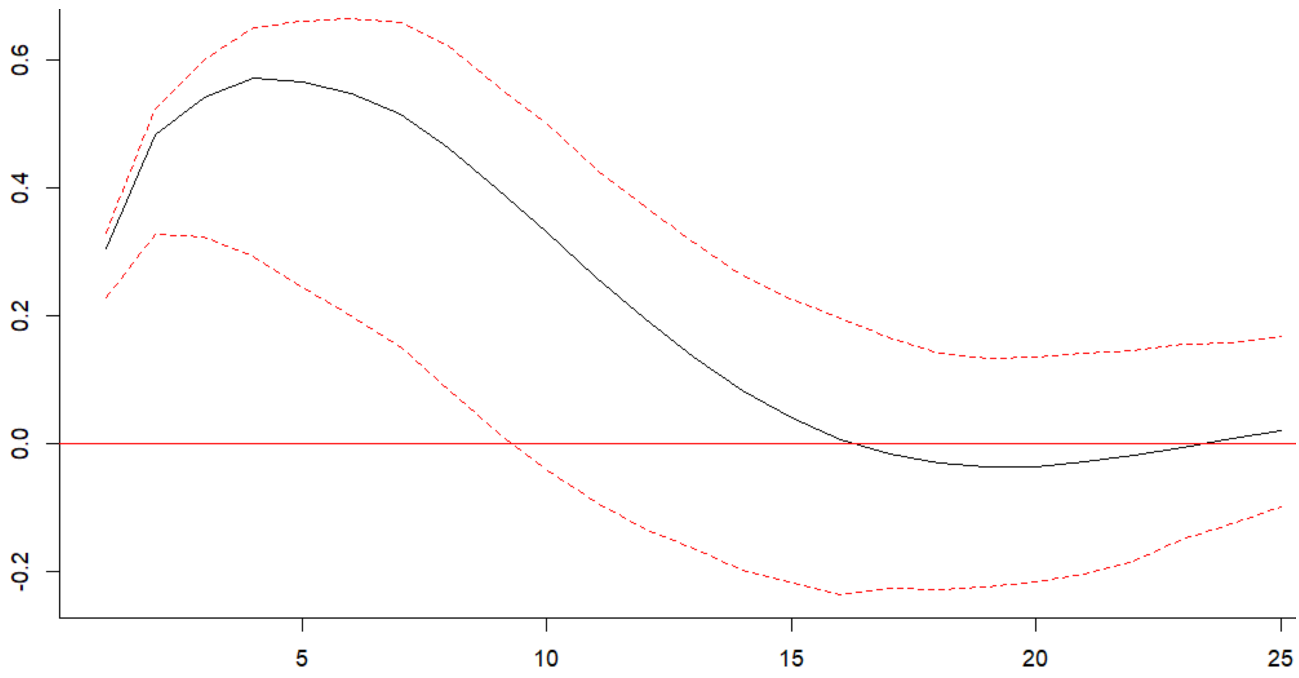

Figure 3 Impulse response function

Another very large topic is confidence intervals of IRF. Again, there is a vast body of literature about them, covering a number of approaches. One used in this thesis is the bootstrap method, which allows for computational estimation of confidence intervals from an existing sample by resampling from it and repeating IRF calculation many (thousands of) times. Bootstrap-calculated 95% confidence interval is shown in red dotted lines in the figure 3.

When the number of time series included into the analysis grows, identification becomes more and more difficult, and structural VAR method eventually stops working, when the amount of time series exceeds the number of observations. And if applied to only a limited number of time series, standard structural VAR can produce misleading results. One of the most known examples is the price puzzle. The price puzzle is often observed in simple structural VARs and means that contractionary monetary policy's immediate result is an increase in inflation, which contradicts the economic theory. Consensus explanation is that a low-dimensional structural VAR inevitably misses some important information (Walsh 2017.)

3.1.3 VAR extensions

One of the ways to address the missing information problem is FAVAR (Factor Augmented VAR), suggested by Bernanke et al. (2005). The idea behind it is that the time series can be separated into series of interest and others, which in turn can be approximated by a smaller number of common factors. VAR model then takes the form:

$$\mathrm{B(L)}\begin{bmatrix} F_t \\ z_t \end{bmatrix} = \mathrm{w_t}$$

where $B(L)$ is lag polynomial, w_t white noise stochastic vector, z_t variables of interest, and F_t unobserved factors, which can be expressed by equation:

$$x_t = \Lambda^F F_t + \Lambda^z z_t + e_t,$$

where x_t is observed variables vector, Λ^F matrix of factor loadings, and Λ^z coefficient matrix. Factors F_t can be estimated by means of principal component analysis from the time series sample data. What is left is then a structural VAR of a lesser size. (Kilian & Lütkepohl 2017.)

The same objective can be achieved also by using the Bayesian shrinkage. Instead of observations, model parameters are considered stochastic, and some of the parameters are assumed to follow random walk with drift (so-called "Minnesota prior"):

$$Y_t = c + Y_{t-1} + u_t$$

Interdependence matrix elements are assumed to be normally distributed, and closeness to this distribution is approximated by hyperparameters (two in the Minnesota prior). Also, numerous other priors are available for selection.

This technique allows to drastically reduce a number of estimated parameters in the VAR model, but results still remain consistent. Bayesian methods generally require more computational power, but that has ceased to be a problem. (Kilian & Lütkepohl 2017.)

Global VAR (GVAR) methodology originally developed by Pesaran et al. (2004) is especially suited to studies about the euro area, because it allows to account for a group of interdependent countries. VAR model for nth country is then as in expression:

$$y_{nt} = \mathrm{v}_n + A_n \mathrm{Y_{n,t-1}} + \mathrm{W}(L) y^*_{nt} + u_{nt},$$

where v_n is again constant term, A_n parameter interdependence matrix, $W(L)$ lag polynomial, and y_{nt}^* contains aggregated variables about other countries. Aggregation can be performed as a weighted average based on some metric, for example, share in the world (or euro area) trade.

There are many other VAR-related methodologies (Dynamic Factor VAR Models, VARX, Spatial VARs to name a few), and more are continuing to emerge. This area of econometrics is developing actively.

One alternative approach to VAR is the Local Projections methodology, originating from Jorda (2005) and used, for example, by Inoue and Rossi (2021) to study the monetary policy effects in the USA. It requires less restrictions and assumptions than VAR but for the cost of a noisier IRF (Kilian & Lütkepohl 2017).

3.1.4 VAR with the external instrument identification

In this thesis I utilize VAR with the external instrument identification, which is originated in Stock and Watson (2012) and Mertens and Ravn (2013), and also used in Altavilla et al. (2019), which I closely follow.

Idea behind is this: instead of trying to estimate structural shocks from the target time series of interest, solving identification problems along the way, this method relies on the outside help in the form of the external instrument variable.

Procedure described next is per Gertler and Karadi (2015) and for a one-dimensional instrument variable. It can be also extended into vector instruments (Mertens & Ravn 2013). Let's consider a structural VAR:

$$\mathrm{B_0 Y_t} = \sum_{\mathrm{j=1}}^{\mathrm{p}} \mathrm{B_j\, Y_{t-j}} + \varepsilon_\mathrm{t}$$

which can be rewritten as a reduced-form VAR by multiplying by B_0^{-1} (renamed to S in the further considerations):

$$Y_t = \sum_{j=1}^{p} A_j\, Y_{t-j} + \mathrm{u_t},\ \mathrm{u_t} = \mathrm{S}\varepsilon_\mathrm{t}$$

where $A_j = B_0^{-1}B_j$ and $\boldsymbol{u}_t$ is reduced-form shock vector.

Structural shock vector ε_t can be divided into ε_t^p policy shock of interest (scalar) and other shocks vector ε_t^q. Because we are only interested in impulse responses to the policy shocks, we must identify only one column $\boldsymbol{s}$ of matrix S, corresponding to ε_t^p:

$$Y_t = \sum_{j=1}^{p} A_j\, Y_{t-j} + \mathrm{s}\varepsilon_\mathrm{t}^\mathrm{p}$$

Let us assume $\boldsymbol{Z_t}$ is an external variable. By the instrument variable assumption, it should be correlated with the policy shocks ε_t^p, and uncorrelated with other shocks ε_t^q:

$$\mathrm{E}\left[\mathrm{Z_t}\varepsilon_\mathrm{t}^\mathrm{p}\right] = \phi,$$

$$\mathrm{E}\left[Z_t\varepsilon_t^q\right] = 0$$

Matrices A and vector u_t can be directly estimated from the reduced-form VAR by least squares. Remaining estimates can be then obtained through two-stage regression as follows:

- $\boldsymbol{u_t}$ can be split into 2 parts: u_t^p - policy indicator residual, and $\boldsymbol{u_t^q}$ - vector of remaining residuals. First stage regression yields fitted values $\hat{u}_t^p$:

$$u_t^p = Z_t\widehat{u_t^p} + \nu.$$

These values exhibit residual's dependence on the policy shock.

- Vector $\boldsymbol{s}$ can also be split into $\boldsymbol{s^q}$ and s^p, where $\boldsymbol{s^q}$ is a response of $\boldsymbol{u_t^q}$ to policy shock ε_t^p. Second stage regression thus produces an estimate of $\boldsymbol{s^q}/s^p$:

$$u_t^q = \frac{s^q}{s^p}\widehat{u_t^p} + \xi.$$

It can be shown that from obtained s^p, $\boldsymbol{s^q}$ and A it is possible to compute the desired IRFs.

Confidence intervals for IRFs can be calculated by various methods, including different bootstrap variants.

3.1.5 Monetary policy surprises identification

One of the ways to identify a monetary policy shock is by utilizing monetary policy surprises (see chapter 2.3). Surprises can be detected from high-frequency quote data in the moments of policy changes announcements and related press conferences, as is depicted in figure 4:

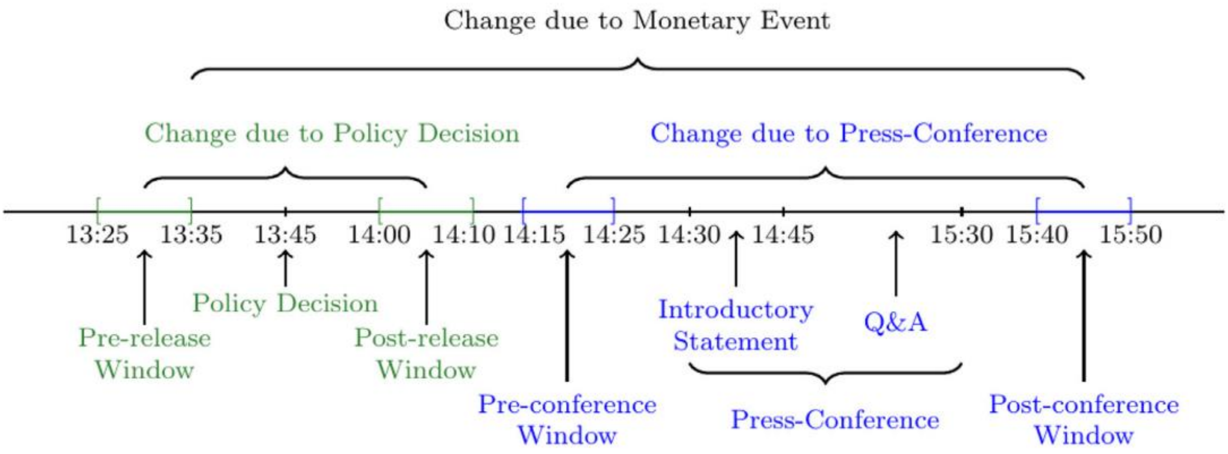

Figure 4 Monetary announcement timeline. Picture: Altavilla et al. (2019), CC BY 4.0

If an event is surprising, the trading rate of an asset shows a sudden increase or decrease at the observed time window.

Arguably there are no such universal assets that each of them corresponds to one particular dimension of the monetary policy exclusively. Rather, it makes sense to monitor changes in many parameters and group them. One method of this is to use classic principal component analysis, as, for example did Gürkaynak et al. (2005). According to them, obtained principal components (factors) can be used as a metric, which captures the types of monetary policy surprises:

$$\mathrm{X} = \mathrm{F}\Lambda + \varepsilon,$$

where X is observation matrix (assets x observations), F factor matrix (factor number much less than assets number), Λ loadings, ε error term.

The number of factors is selected by the cumulative proportion of variance explained. Wald test can be utilized for the null hypothesis that the selected number of factors is indeed sufficient. (Gürkaynak et al. 2005.)

Raw factors are not necessarily possible to interpret economically, but they could be rotated so each of them has an economic meaning, and their explanatory power persists (Gürkaynak et al. 2005). In practice, such matrix U can be calculated numerically so that the expression holds:

$$\mathrm{X} = \tilde{F}\widetilde{\Lambda} + \epsilon^{j},$$

where $\tilde{F} = \mathrm{FU}$ and $\widetilde{\Lambda} = U'\Lambda$.

The rotated factors explain the same proportion of variance as the original latent factors.

The advantage of this factor method is that it is based on hard timestamped data about real asset prices, which have direct impact on the markets.

Other indirect identification schemes are also possible. One example is the heteroskedasticity-based identification, which was presented in Rigobon and Sack (2003). The core assumption is that variance of asset price is generally homoskedastic, but monetary policy surprises introduce some heteroskedasticity, which could be detected. The authors themselves admit that this technique is far from perfect.

As factors are thus identified, it is possible to check whether they affect other economic variables. In case they are measured at the same moments of time, regression models can be applied. If a statistically significant dependence is detected, it is possible to establish also a causality, because an assumption that central bank's measures follow from some transitory movements in asset prices is not reasonable.

Next section provides an overview of the empirical studies about the euro area using methods described above and similar to them.

3.2 Selected results for the euro area

In this section I present findings from the recent and most relevant empirical literature about the euro area's monetary policy effects. Particularly, I report the methodology used and results about cross-country differences.

3.2.1 Monetary policy effects

Jarociński (2010) studied differences among the group of euro area countries including Finland and new EU member states from Eastern Europe (Czech Republic, Hungary, Poland and Slovenia). For that, he employed a hierarchical linear VAR model with Bayesian prior. The author argues that this method drastically reduces sensitivity to small samples and reduces confidence intervals. The new member states had their own currencies in the research period, which were not fixed to the euro, and ECB's actions were controlled for, so monetary policy shocks were considered domestic. The author finds that impulse responses were broadly similar, with more volatility observed in countries with higher inflation.

Several years later and the situation has already changed. Ciccarelli et al. (2013) used panel VAR containing quarterly differenced output, interbank lending volumes, interest rates and some other variables at the individual country level. The authors find that during the financial crisis transmission mechanism became heterogenous, with strongest effect for countries under sovereign stress (Greece, Ireland, Italy, Portugal, Spain). Also, the authors find credit channel transmission to be stronger in stressed countries.

Barigozzi et al. (2014) used the Structural Dynamic Factor model, consisting of 237 quarterly time series of aggregate variables (GDP, consumer price index (CPI), etc.) from 1983 to 2007, taken from Eurostat and ECB. These variables are transformed in two factors: the common euro area factor and the idiosyncratic country-specific factor. The authors find differences between North and South Europe' responses in prices and unemployment, but not in output. As an explanation, they offer stickier prices, rigid labour market structure and less market competition in Mediterranean countries. As to Finland, in CPI measurements its economy generally reacts as expected, in contrast to some countries whose economies provide almost zero response. The authors argue that differences should be addressed by national financial policy, similarly to Georgiadis (2015). They also state that after the introduction of the euro, prices became more flexible and reaction to interest rate changes became more similar across member countries.

Georgiadis (2015) studied the euro area's aggregated output growth and inflation's effects on countries' economies by the GVAR method, in a manner similar to Burriel and Galesi (2018). One of the key findings is that countries with a higher interest rate -affected demand react stronger, and the same applies for countries with a rigid labour market. For example, in case of tightening monetary shock, the real GDP drops the most in Slovakia, Finland and Slovenia, and the least in Portugal, Belgium and Austria. Also, the author emphasizes the importance of country- and even region-specific financial policy in such reaction.

Cavallo and Ribba (2015) studied the effects on the real economic variables by a modified structural VAR method, where variables of interest are divided into blocks of exogenous (euro area -wide) and endogenous (national level) variables. The authors identified two groups of countries: one where common monetary shocks affect the output the most (Belgium, France, Germany, Italy and Spain), and another group (Greece, Ireland and Portugal), where local national shocks dominate. The authors thus confirm the existence of a division between the so-called North group of strong economies and South group, but their reaction to monetary policy shocks are more or less similar.

Burriel and Galesi (2018) state as well as Jarociński (2010) that after the financial crisis countries reacted to unconventional monetary policy measures heterogeneously, but their result is somewhat opposite. They find that countries with a more resilient banking system benefit more from unconventional monetary policy measures, and spillover effects amplify that also. Interest rate changes cause a stronger and more persistent effect. Finland along with Germany, Netherlands etc is in that group of benefitting countries with a relatively high capital ratio. Methodology used is the Global VAR, consisting of the VAR model of the global monetary policy and national-level VARs, which captures also cross-country dependencies. Data variables include GDP and Harmonized Index of Consumer Prices (HICP), EONIA, MRO rate etc.

Burgard et al. (2019) studied output and price levels by means of their novel mixture VAR (Logit-MVAR). The authors argue that monetary policy transmission works better in the so-called crisis state as opposed to the normal state, although effects last shorter. The crisis state manifested itself obviously at the financial crisis of 2008, and also to some extent during recessions and sovereign debt crises.

Focus of the empirical part of this thesis is on the effects of monetary policy surprises. One of such studies is by Jarociński and Karadi (2020), where surprises are identified in EONIA swap and EUROSTOXX50 during ECB's announcements. Their results indicate that nominal price stickiness in the euro zone is high and financial frictions low.

Mandler et al. (2022) used Bayesian VAR to study only France, Germany, Italy, and Spain (same group as Altavilla et al. (2019)) focusing on cross-country differences. Variables included are real GDP, HICP, money stock, loans to the private sector, and 5-year sovereign bond yields. The authors find that Germany and France react strongest in terms of output and long-term interest rates and weakest in price level. As an explanation they offer manufacturing/services ratio and competition in the banking sector in these countries.

Corsetti et al (2022) confirm some of the results of Georgiadis (2015). They find that the combination of housing ownership, household liquidity and wage rigidity mostly define how economies react to the monetary policy shocks. Financial variables and GDP are found to be less heterogenous than consumption and consumer prices. As to Finland, consumption drops 10 times more than that of Germany. Reaction to the tightening measures is also strong: drop in GDP is second deepest of EU after Ireland, drop in stock prices the deepest. Methodology shares some elements with Altavilla et al. (2019), namely, they develop a Structural Dynamic Factor model, where surprises' identification is likewise based on a high-frequency data.

Odendahl et al. (2024) studied monetary policy surprises' effects on a set of variables close to that of Altavilla et al. (2019) and using similar methodology. Their finding is that the response to the interest rate changes is homogenous, but to unconventional measures varies significantly depending on the risk premia for these countries.

Kho (2025) studied monetary policy effects on bank deposit rates via local projections. Surprises' identification is based on high frequency changes in 1-month OIS. Herfindahl–Hirschman Index (HHI) as a measure of competition in banking sector is controlled for. The author shows that more competitive banking sector reacts slower to contractionary measures (increasing rates) and faster to expansionary (decreasing rates). Finland along with Netherlands is in a group with highest HHI (least competitive banking sector), while Germany and Italy in a low HHI group.

There does not seem to be a definite consensus as such among these results, but in general the euro area's monetary policy is proven to serve its purpose, although with a varying degree of efficiency for different countries. Very little if any detrimental effect of it on any economy has been detected, which advocates for the ECB's mission. Differences in the monetary policy transmission are explained by various features of economies in question depending on the methodology and data used.

Depending on the research setup and time, some groups and coalitions have been identified, such as Cavallo and Ribba's (2015) North and South (Mediterranean) group. France, Germany and Netherlands are often found in the same (core) group, and the same holds for peripheral and newer member states.

3.2.2 Business cycles synchronization

As can be seen from the economic theory (chapter 2.2), common monetary policy works best if economies it is being applied to are in the same stage of a business cycle. In other words, business cycles of countries in question should be synchronized.

According to a number of studies including Campos et al. (2019), business cycle synchronization of the euro zone has been increasing since the introduction of the euro and the common market. Guerini et al. (2023) emphasize that notwithstanding the common synchronization trend, there can still be distinguished groups of countries, which are less synchronized, such as North and South groups.

Arčabić and Škrinjarić (2021) find that spillovers among euro area countries play a great role in the business cycles synchronization. According to them, newer euro area members are more affected by them than older ones. Synchronization increases in periods of downturn, and responses to the common monetary policy are quite similar.

One of obvious benefits of synchronization is that it leads to less disagreement in ECB decisions on economic grounds. If member countries are in a similar position, there is less incentive to form coalitions and lobby measures that can potentially be detrimental to others.

However, the role of the monetary policy in the synchronization process is difficult to assess, as is generally the case with causality. Euro area largely coincides with the European Union, so the reasons for synchronization can be not only the monetary policy, but also the fiscal policy, free labour and capital movement, lack of trade barriers, etc. Effects of monetary policy measures can be identified statistically, but this does not form 100% conclusive evidence for the causality.

4 Empirical research

In this chapter I describe the empirical research I have conducted for this thesis. I closely follow the setup and procedure of Altavilla et al. (2019). Reasons behind this choice are following:

- this paper introduced a new and credible method of assessing effects of monetary policy surprises, which is based on statistical significance. Every assumption is tested and robustness checks performed. It is cited a lot in the recent literature.
- authors maintain a public database of monetary policy surprises, which is open for researchers and is updated regularly. ECB itself provides support for this project.

This provides an opportunity to check whether the conclusions of the original paper still hold with the newer data. Second, it is possible to combine this database with additional time series, in case of this thesis with Finnish sovereign bonds' yields. Third, as the authors are focusing on the general approach and results, I am paying particular attention to cross-country differences in them, namely, how different are findings for Germany, France, Spain, Italy and Finland. And finally, I also combine this setup with the analysis of term premia for these countries as per approach of Gertler and Karadi (2015).

4.1 Procedure

The starting point for this research is Euro Area Monetary Policy Event-Study Database (EA-MPD), which is maintained by Altavilla et al. and publicly available from ECB's web site. This database is created from monetary policy surprises identified from high-frequency trading data. This method is described in chapter 3.1.5.

Altavilla et al. (2019) find that if a monetary event is surprising, markets start to react in the press release time window and the press conference window. The authors analyse the effects on several assets including government bonds of Germany, France, Italy and Spain, and also on OIS (overnight index swap, ECB's interest rate) and STOXX50E. Essentially, if a monetary event is qualified as a surprise, jumps in the trading rates of these assets at the time of this surprise are collected into the EA-MPD database.

The key asset for the study is OIS at different maturities, as in several other studies, for example Odendahl et al. (2024). Altavilla et al. (2019) consider it as a proxy for the risk-free interest rate in the euro area, particularly 1-month OIS as a measure of a short-term surprise.

4.2 Factor extraction and testing

The data from the asset rates surprise movements can be grouped into factors by means of principal component analysis and rotation technique, first described in Gürkaynak et al. (2005) and widely used since then. Altavilla et al. (2019) first determined (by Wald test) that overall number of statistically significant factors is 1 in press release window and 3 in press conference window.

Then, for factor rotation, the following requirements have been set:

- second and third factor should not be loaded on 1-month OIS, i.e. first factor should represent short term effects;

- third factor should not have explanatory power in the period before 2008 crisis, i.e. to be QE-related, as per Swanson (2021).

Thus, total of 4 rotated factors in the press release and the press conference time windows have been identified.

In the press release window: "Target" factor - captures communication surprises, which reflect into short term assets (up to 1 year)

In the press conference window:

- "Timing" factor - short run monetary policy surprise (6 months maturity)

- "Forward Guidance" - medium run (2 years maturity)

- "QE" - long run (10 years maturity), present only after 2014.

I check whether these prerequisites of the original paper still hold with the updated data, namely, the number of factors and the variance decomposition. Wald test results and variance decomposition appeared to be close, details are reported in Appendix 1. The base for this research is thus established.

Next, I proceed to checking the impact of the factors on the sovereign bonds.

4.3 Sovereign bonds

Impacts on the sovereign bonds are assessed by the OLS regressions. In the original paper, authors also include the control variable IJC (initial jobless claims in USA), because announcements about these claims frequently coincide with ECB's announcements. The authors find that it is not statistically significant in any of the regressions and state that omitting it does not contaminate the results.

I retain the time period split of the original paper (for an opportunity to compare results) and add the new period 2019-2023 for the newer data. Originally, I planned to include Finland's government bonds of the same maturity for comparison, but unfortunately getting high-frequency trading data is not feasible for an independent student.

For the next tables (1 and 2) cell values are yearly percentage difference when the independent variable changes one standard deviation. Robust standard errors calculated, significance levels are: * 10%, ** 5%, *** 1%

Table 1 2-, 5- and 10-year sovereign bonds of Spain, Italy, France and Germany, press release window

2002 - 2007												
	ES2Y	ES5Y	ES10	IT2Y	IT5Y	IT10Y	FR2Y	FR5Y	FR10	DE2Y	DE5Y	DE10
Target	0,07 (0,10)	-0,02 (0,12)	-0,06 (0,09	0,10 (0,10)	-0,02 (0,11)	-0,05 (0,09)	-0,05 (0,11)	-0,03 (0,11)	-0,05 (0,09)	0,02 (0,08)	-0,03 (0,11)	-0,05 (0,09)
Obs.	72	72	72	72	72	72	72	72	72	72	72	72
R^2	0,022	0,002	0,02	0,05	0,001	0,02	0,01	0,003	0,02	0,002	0,003	0,02
2008-2013												
Target	0,44** (0,18)	0,31** (0,14)	0,29* (0,15)	0,50** (0,19)	0,44** (0,18)	0,19* (0,12)	0,46*** (0,08)	0,37*** (0,11)	0,14 (0,09)	0,50*** (0,05)	0,36*** (0,09)	0,19 (0,08)
Obs.	71	71	71	71	71	71	71	71	71	71	71	71
R^2	0,21	0,14	0,16	0,27	0,20	0,07	0,44	0,27	0,05	0,60	0,26	0,06
2014-2018												
Target	0,96*** (0,3)	0,96*** (0,36)	0,97* (0,56)	1,23*** (0,39)	1,1*** (0,40)	1,04* (0,53)	1,16*** (0,21)	1,05*** (0,22)	0,65* (0,38)	1,09*** (0,19)	1,01*** (0,19)	0,59*** (0,21)
Obs.	44	44	44	44	44	44	44	44	44	44	44	44
R^2	0,35	0,24	0,12	0,16	0,14	0,12	0,53	0,34	0,09	0,58	0,46	0,17
2019-2023												
Target	-0,08 (0,10)	-0,24 (0,18)	-0,21 (0,17)	-0,17 (0,27)	-0,20 (0,27)	-0,18 (0,27)	-0,06 (0,23)	-0,19 (0,19)	-0,19 (0,17)	0,06 (0,19)	-0,11 (0,15)	-0,17* (0,10)
Obs.	39	39	39	39	39	39	39	39	39	39	39	39
R^2	0,01	0,04	0,04	0,01	0,01	0,01	0,003	0,02	0,03	0,004	0,01	0,06

In periods 2002-2007 and 2018-2023 almost no significant effects whatsoever are observable. Variance itself during these years was small (Altavilla et al. 2019), from what one can conclude that markets did not find anything particularly surprising in the press release window.

2008-2018: France and Germany have slightly higher coefficient of determination (R^2), but overall, not much of variance explained, especially for 10-year sovereign bonds. However, for shorter bonds results are statistically significant, and coefficient values are on the same level for all countries.

Table 2 Sovereign bonds, press conference window

2002 - 2007												
	ES2Y	ES5Y	ES10	IT2Y	IT5Y	IT10Y	FR2Y	FR5Y	FR10	DE2Y	DE5Y	DE10
Timing	1,05*** (0,07)	0,76*** (0,06)	0,38*** (0,07)	0,97*** (0,05)	0,70*** (0,08)	0,35*** (0,07)	0,96*** (0,06)	0,69*** (0,08)	0,37*** (0,07)	1,00*** (0,04)	0,50*** (0,15)	0,37*** (0,07)
FG	0,95*** (0,08)	0,96*** (0,06)	0,65*** (0,05)	1,04*** (0,05)	0,95*** (0,06)	0,63*** (0,06)	1,07*** (0,06)	0,94*** (0,06)	0,65*** (0,06)	1,02*** (0,02)	1,14*** (0,13)	0,64*** (0,06)
Obs.	67	67	67	67	67	67	63	65	67	67	67	67
R^2	0,92	0,92	0,76	0,96	0,86	0,74	0,95	0,89	0,74	0,97	0,85	0,74
2008-2013												
Timing	0,46*** (0,13)	0,28** (0,13)	0,12 (0,11)	0,54*** (0,17)	0,22 (0,18)	0,14 (0,11)	0,84*** (0,06)	0,44*** (0,11)	0,21*** (0,07)	0,92*** (0,03)	0,60*** (0,05)	0,27*** (0,07)
FG	0,88*** (0,07)	0,74*** (0,08)	0,36*** (0,08)	0,96*** (0,09)	0,79*** (0,10)	0,33*** (0,08)	0,99*** (0,04)	0,86*** (0,05)	0,38*** (0,07)	0,99*** (0,02)	0,85*** (0,04)	0,37*** (0,05)
Obs.	71	71	71	71	71	71	70	70	71	71	71	71
R^2	0,54	0,34	0,10	0,44	0,25	0,07	0,94	0,79	0,47	0,98	0,83	0,46
2014-2018												
Timing	0,91*** (0,31)	1,19*** (0,43)	0,69* (0,40)	0,93*** (0,32)	1,22** (0,48)	0,83* (0,46)	0,95*** (0,13)	0,83*** (0,16)	0,30 (0,19)	1,02*** (0,04)	0,82*** (0,09)	0,22*** (0,07)
FG	0,71*** (0,15)	0,97*** (0,26)	0,92*** (0,26)	0,74*** (0,16)	1,04*** (0,28)	1,07*** (0,31)	0,91*** (0,11)	1,06*** (0,13)	0,81*** (0,16)	1,00*** (0,02)	0,89*** (0,05)	0,47*** (0,04)
QE	0,55*** (0,10)	0,70*** (0,12)	1,42*** (0,16)	0,55*** (0,10)	0,92*** (0,21)	1,68*** (0,18)	0,43*** (0,08)	0,97*** (0,10)	1,56*** (0,13)	0,30*** (0,02)	0,78*** (0,56)	1,09*** (0,04)
Obs.	44	44	44	44	44	44	44	44	44	44	44	44
R^2	0,72	0,63	0,78	0,57	0,57	0,72	0,85	0,90	0,92	0,99	0,97	0,99
2019-2023												
Timing	1,53 (0,92)	0,98 (0,62)	0,56 (0,66)	0,50 (1,16)	0,25 (1,36)	-0,02 (1,24)	2,18** (0,89)	1,15** (0,57)	0,74 (0,53)	0,70*** (0,08)	0,54*** (0,05)	0,53*** (0,05)
FG	0,79*** (0.10)	0,91*** (0,09)	0,63*** (0,14)	0,99*** (0,22)	0,93*** (0,25)	0,78*** (0,25)	1,02*** (0,12)	1,01*** (0,10)	0,63*** (0,08)	0,96*** (0,02)	0,82*** (0,02)	0,54*** (0,02)
QE	-0,11 (0,22)	0,64*** (0,17)	0,79*** (0,25)	0,14 (0,48)	-0,06 (0,60)	0,36 (0,62)	0,23 (0,15)	0,76*** (0,16)	1,01*** (0,18)	0,37*** (0,02)	0,84*** (0,02)	1,02*** (0,02)
Obs.	39	39	39	39	39	39	39	39	39	39	39	39
R^2	0,52	0,77	0,57	0,33	0,2	0,18	0,76	0,82	0,76	0,99	0,99	0,99

In the period 2002-2007 no significant differences in effects among countries. R^2 is high.

2008-2013: Germany and France have much higher R^2, also Timing factor's effect is much stronger on shorter bonds. Probably stronger economies of these countries allow for more predictability in terms of monetary policy. For Spain and Italy R^2 is quite low, indicating the relative importance of idiosyncratic reasons over monetary policy surprises.

2014-2018: best explanatory power, all coefficients except one (Timing on French 10-year bonds) are statistically significant. Here longer bonds of Germany react weaker than others to all factors. Possible interpretation is that introduction of QE made markets follow monetary policy surprises more accurately, Germany being the most reliable economy.

2019-2023: effects of FG are strong and statistically significant for all countries. R^2 for Germany is very high with coefficients somewhat smaller than others. For Italy R^2 is particularly low, and coefficients of QE and Timing are not statistically different from zero.

The authors also perform a non-linearity robustness check which I omit due to closeness of the results.

The main observation from above is that for stronger economies, such as Germany and France, the coefficient of determination R^2 is systematically higher (sometimes up to 0,99), so that the overall monetary policy actions' effect on their sovereign bonds is stronger. For other countries their idiosyncratic factors play a more significant role.

Worth noting is that by quantity most of the surprises are detected in the press conference window, in some periods virtually all, as opposed to the press release window.

Next, I check what do OIS patterns look like in the updated data.

4.4 Overnight Index Swap (OIS)

Here I check monetary policy factors' impact on OIS with the newer data, to provide a continuation and comparison with the original paper (table 3). Content and conventions of this table are like these of tables 1 and 2.

Table 3 Estimated effects of monetary policy surprises on OIS, 2019-2023

Press release window							
	OIS 1M	OIS 3M	OIS 6M	OIS 1Y	OIS 2Y	OIS 5Y	OIS 10Y
Target	0,99*** (0,01)	0,83*** (0,11)	0,65*** (0,11)	0,37** (0,15)	0,06 (0,19)	-0,11 (0,15)	-0,17* (0,10)
Observations	39	39	39	39	39	39	39
R^2	0,99	0,71	0,54	0,14	0,004	0,01	0,06
Press conference window							
Timing	0,04 (0,10)	0,62*** (0,08)	1,19*** (0,08)	1,48*** (0,09)	0,70*** (0,08)	0,54*** (0,05)	0,53*** (0,05)
FG	-0,07* (0,04)	0,08*** (0,02)	0,48*** (0,02)	0,87*** (0,03)	0,96*** (0,02)	0,82*** (0,02)	0,54*** (0,02)
QE	0,07** (0,03)	0,03 (0,02)	-0,03 (0,02)	0,05** (0,02)	0,37*** (0,02)	0,84*** (0,02)	1,02*** (0,02)
Observations	39	39	39	39	39	39	39
R^2	0,30	0,77	0,96	0,99	0,99	0,99	0,99

Results are very similar to that of the original paper, namely, Target factor's effect is strongest for short term OIS, that of FG and QE for medium and long term respectively. Timing factor's effect peaks at 6-month and 1-year OIS. Factor classification principle therefore still holds.

Once the factor setup is thus concluded, it is possible now to proceed to the analysis of factors vs daily time series with VAR.

4.5 Vector autoregressions

To analyse the persistence of surprise effects I use VAR with identification by external instrument, following the original paper's methodology, which is described in section 3.1.4. VAR is applied to expanded daily time series of the following asset rates: sovereign bonds, OIS, STOXX50E, EUR/USD exchange rate and 2-year ILS (inflation-linked swap). Additional and newer data is obtained from the LSEG Workspace and covers the time span from year 2002 to 2023. The impulse response horizon is 1000 days.

Shocks are identified through external instruments, namely, surprise factor values. Choice of external instrument variables is natural, because their impact is proven by the previous analysis. To achieve that, additional 4 time series are generated for every surprise type, which contain previously calculated factor values on the day of every surprise, and zeroes on other days (see table 4):

Table 4 Example daily data

Date	Target	Timing	FG	QE	LOGSTOXX	LOGEURUSD	FR1Y	DE2Y
3.1.2002	0.805	1.984	-2.01	-0.765	825.14	-10.136	3.17	3.629
4.1.2002	0	0	0	0	824.81	-11.048	3.26	3.684
7.1.2002	0	0	0	0	823.07	-11.597	3.29	3.596
8.1.2002	0	0	0	0	822.26	-11.552	3.31	3.602
9.1.2002	0	0	0	0	822.23	-11.417	3.36	3.729
10.1.2002	0	0	0	0	820.7	-11.552	3.37	3.696

First row corresponds to the surprise day, so factor columns contain calculated values. For subsequent rows until a new surprise these columns contain zeroes.

VAR model (expression 3) is estimated with one instrument at a time to get an impulse response for a respective factor. Using combination of all is also possible, which gives an impulse response to a general monetary policy shock of an unspecified type.

$$Y_t = \mathrm{c} + \sum_{j=1}^{p} A_j\, Y_{t-j} + \mathrm{S}\varepsilon_{\mathrm{t}}, \tag{3}$$

where Y_t is a variable vector, c constant term, A_j interdependence matrices, S shock structure matrix and ε_t white noise. Number of lags p for all models is 12.

First, I check whether daily VAR, where variable vector Y_t contains 2-year OIS, STOXX50E, EUR/USD exchange rate and 2-year ILS, is similar to that of the original. Resulting IRFs are quite close to the published before and are reported in appendix 2. Conclusions of the original paper thus still hold, namely, effects of monetary surprises on these variables are clear and persistent. Some of them, however, have different shapes in different time periods.

Next, I study the persistence of monetary surprises' effects on sovereign bonds through their IRFs to check for any observable differences among countries. Model is the same as in expression 3, but instead of 2-year OIS, respective government bonds are inserted, one at a time.

Results are reported in the figures 5, 11 and 12. Responses are normalized, confidence levels (95%, 90%, 85%, 75%) are calculated via wild bootstrap and shown in dotted lines.

IRFs for 10-year sovereign bonds are presented in the figure 5:

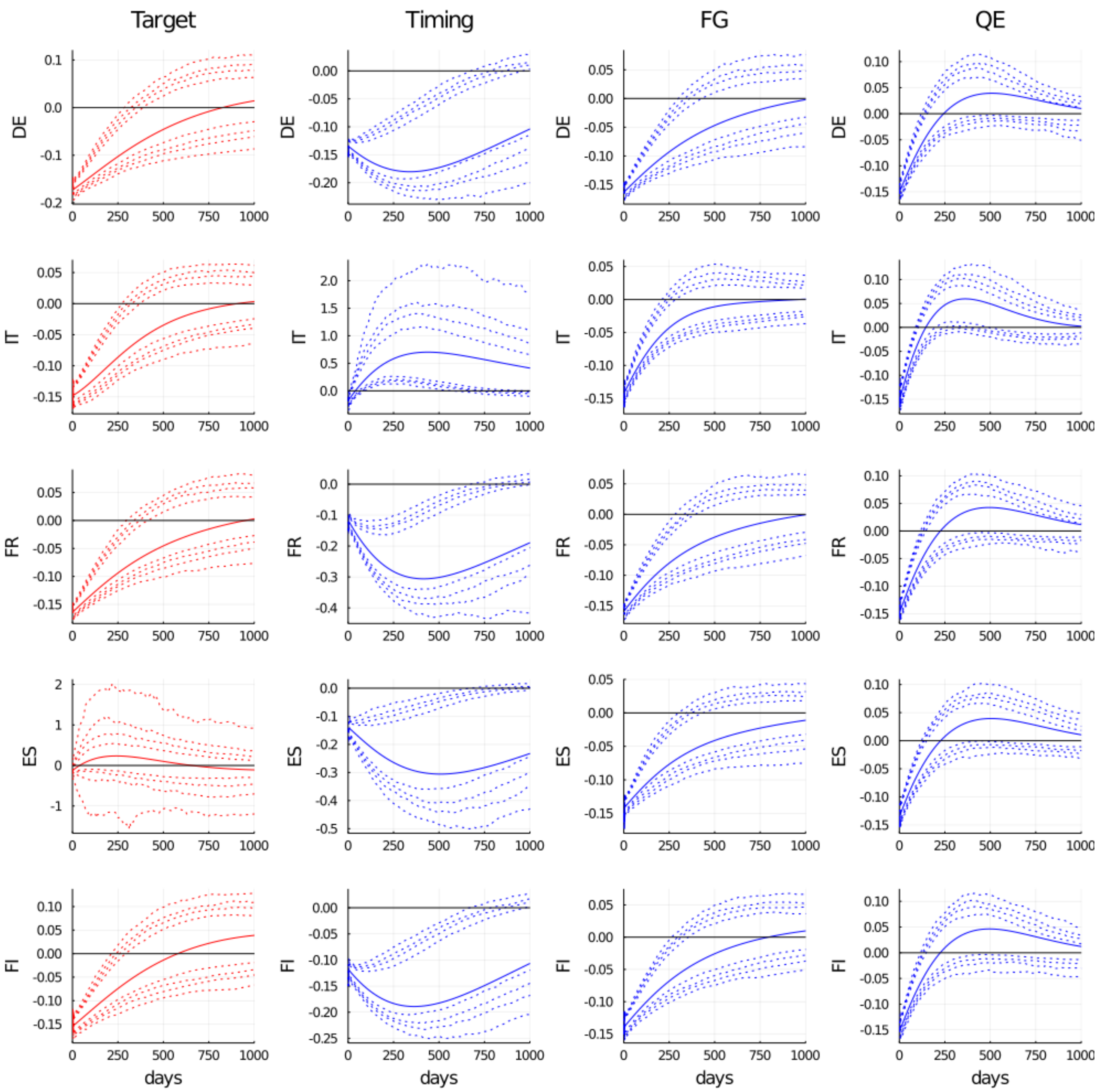

Figure 5 IRF of 10-year sovereign bond rates

Similar charts for 2-year and 5-year bonds are presented in the appendix 3. As can be seen from these graphs, Target and Timing factors show narrower confidence intervals for 2-year bonds, QE shows narrower confidence intervals especially for 10-year bonds, which is in line with the factor classification and original paper's results. Note that response values in these graphics are inverted, original responses are all positive. I keep that and the scaling the same as in the original paper.

Almost all effects show a remarkable persistence lasting for at least half-year, for some combinations even longer. One notable exception is Italy's 10-year bonds and Timing factor, same as in the original research.

Finland's IRFs look similar to those of Germany and France in terms of shape and persistence. Overall, no drastic differences in persistence are observed among countries, except probably Italy in some cases.

Finally, I check the hypothesis of Gertler and Karadi (2015), that term premium should not react to the monetary policy measures, that is, their impulse responses should be flat. For that, I follow their paper's methodology, namely, using the rearranged expression 1:

$$\phi_t^m = i_t^m - E_t \frac{1}{m}\left(\sum_{j=0}^{m-1} i_{t+j}\right),$$

where ϕ_t^m is the term premium, E_t expected value, i_t^m is the long (m=5) bond yield, and i_{t+j} short (1-year) bond yield. I calculate the term premia as a difference between the long bond yield and the short bond yield's expected path. Expected path's values of the future short bond yields are calculated using its IRF from the same VAR model:

$$E_t(i_{t+j}) = i_t IRF_j$$

Because VAR is daily, I take IRF_j values on days 365, 730, 1095 and 1460. Finland's 1-year bonds are not available (do not exist to the best of my knowledge), so for Finland I consider 2-year bond as short, and 6-year bond as long. IRF_j values are then taken on days 730 and 1460.

Results are shown in the figures 6 and 7. In the figure 6 there are IRFs of 5-year government bonds for a general monetary policy surprise, identified by all 4 factors. Solid blue line is the IRF of the bond, black is the IRF of the term premium. Dotted lines are confidence intervals for the bond IRF as in previous graphs.

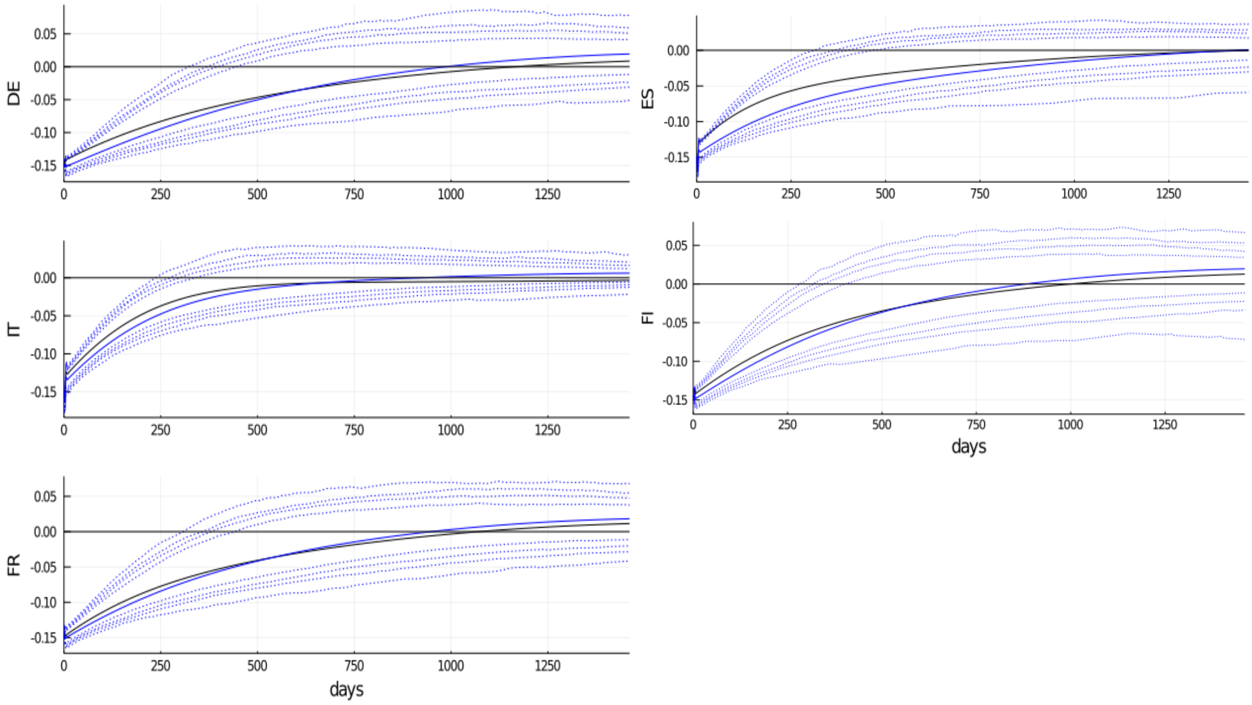

Figure 6 Term premia for a general surprise, 5(6) -year bonds

In this case term premia's IRFs are very close to the bond rates' IRFs, which means that flat IRF hypothesis should be rejected. Term premium seems to react to the shocks indeed. As to the persistence, shortest is observed for Italy and longest for Germany, with others in between. Half-life is roughly from half-year to a year.

Next figure 7 shows the impulse responses for the shock factors separately.

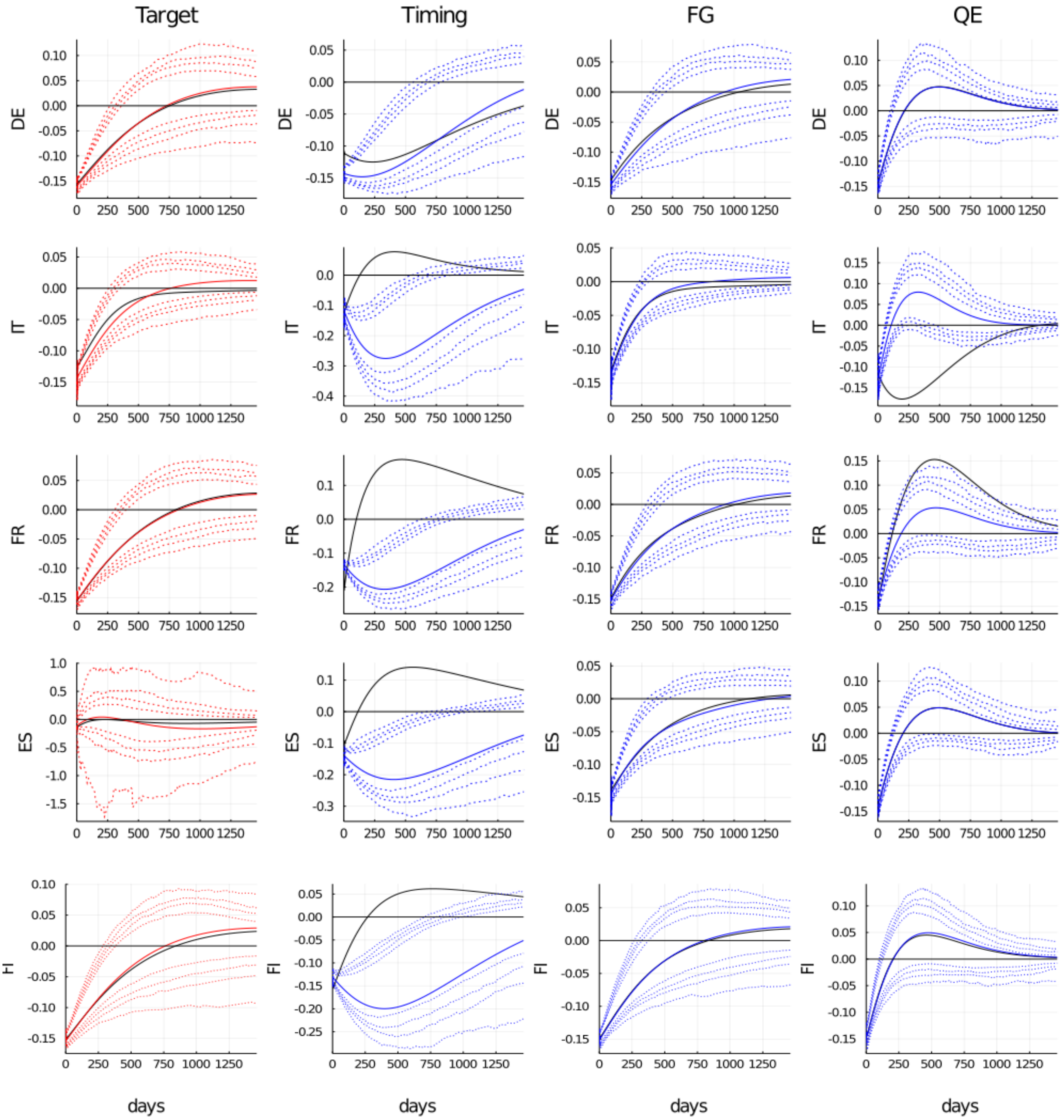

Figure 7 Term premia by factors, 5 (6) -year bonds

In this case IRFs are close not for all factors, especially for the Timing factor. For Italy, France and Spain it could be considered as reverting quickly to zero, indicating that the initial hypothesis of its independence of shocks may hold true.

The graphs for the Target factor, as well as for FG and QE (except Italy), show that IRFs of bond yield and term premium are very close. Term premium = bond yield - expected path, so this means that probably all of the surprise in the bond yield was due to the term premium, and expected path did not react.

Next, I repeat the same experiment for 2-year bonds as long and 1-year bond as short (for Finland 4-year and 2-year respectively. Resulting charts are in the figures 8 and 9.

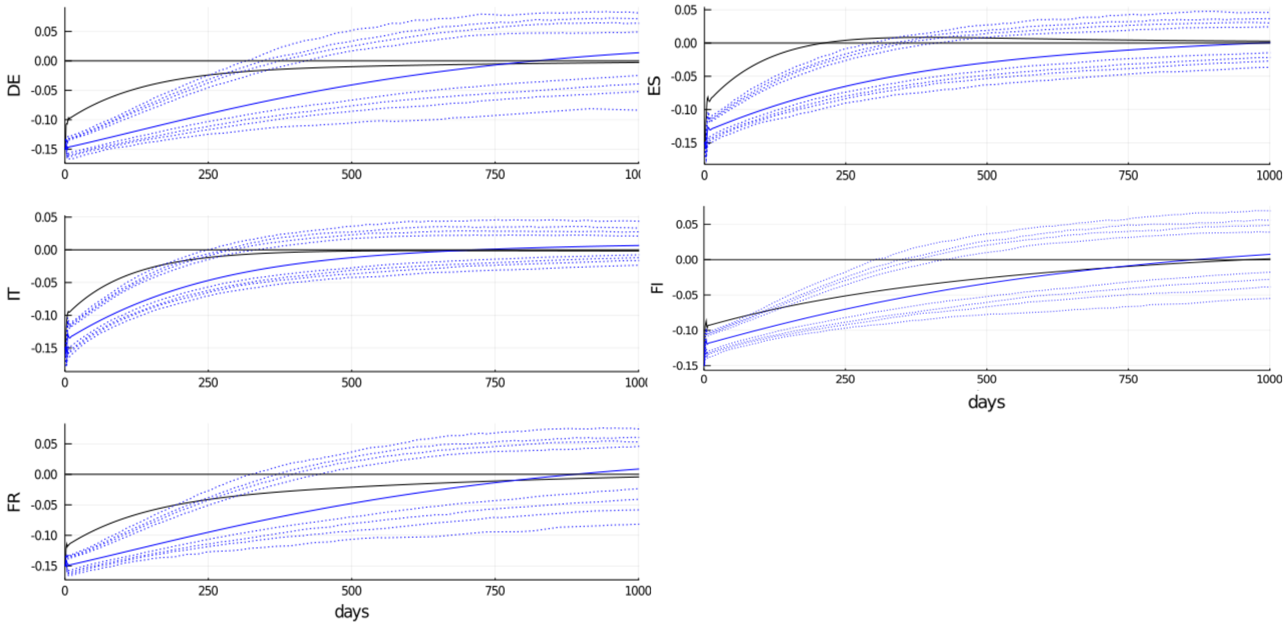

Figure 8 Term premia for a general surprise, 2 (4) -year bonds

Graphs differ significantly from the previous long bond case, term premia's response is weaker. This seems logical because 2 years are not that different from 1 year in absolute terms.

Next figure 9 shows impulse responses for the surprise factors separately again.

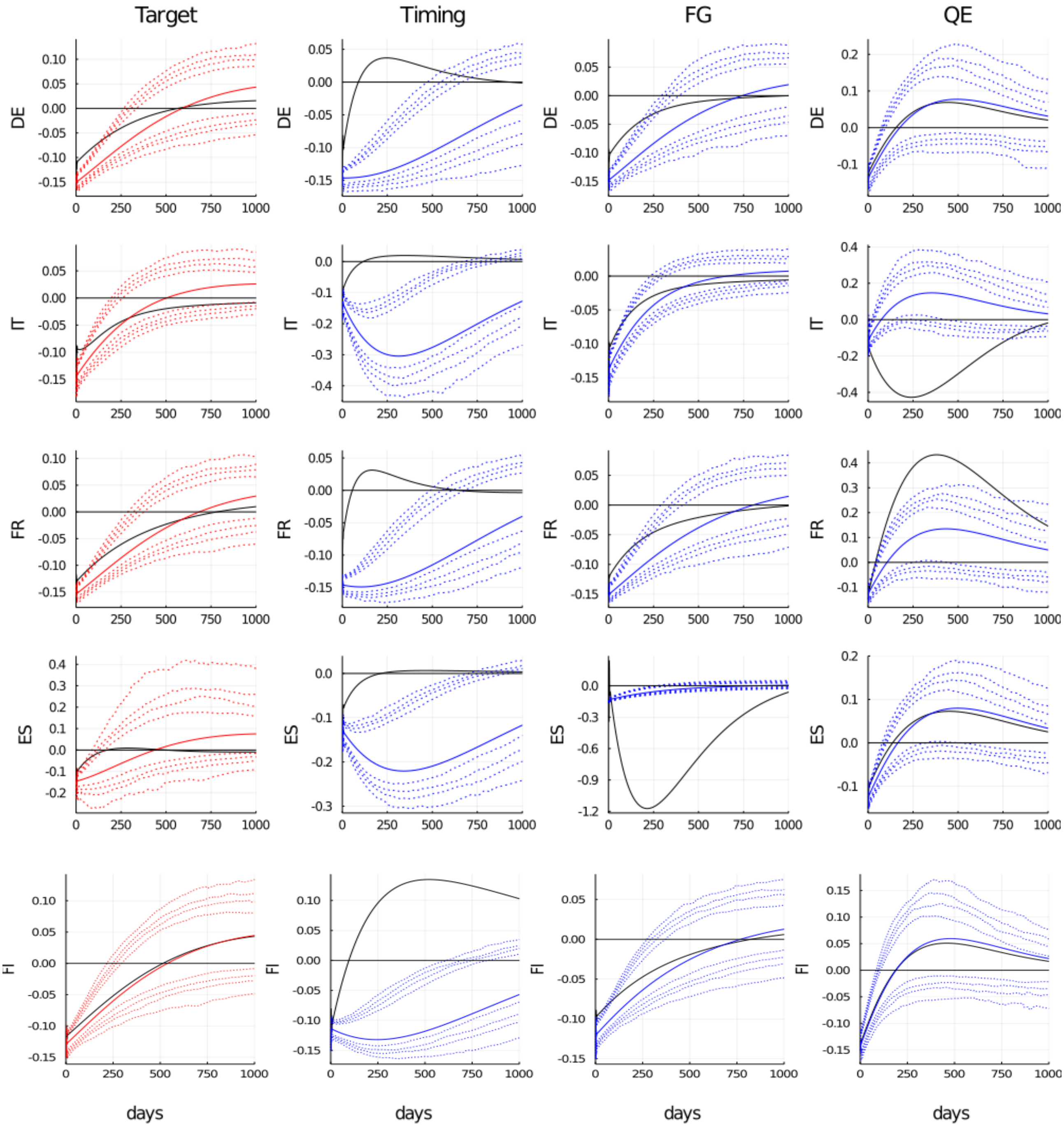

Figure 9 Term premia by factors, 2(4) -year bonds

This is where the most variation in results appears. Responses for the Target factor are now somewhat further apart than in case of 5-year bonds, but not much. As to the Timing factor, none of the term premia's responses are close to the bond ones and could be probably considered flat (except Finland). Finnish responses look close to these of Germany.

Overall, term premium's responses show much more variation among countries than bond rates when decomposed to the factors. This is another argument for the importance of classification of the monetary policy surprises.

Some of the results, especially for general monetary policy surprises, look quite close to these of Gertler and Karadi (2015). It should be noted however, that it is not possible to compare them directly, because Gertler and Karadi used monthly data for their models, whereas the setup of this thesis's calculations is based on the daily data.

Apart from the limited number of cases, hypothesis of the fixed term premium should be rejected. This result is in line with Gertler and Karadi (2015). This implies that some kind of dependence of the term premium on the interest rate should be included in the monetary transmission model.

4.6 Summary

The conducted empirical research produces the following main results:

- measurement methodology of Altavilla et al. (2019) still produces consistent results with the updated and expanded data
- monetary policy surprises affect sovereign bonds' rates in largely similar way, although some differences in effects can still be detected. Germany's and France's bonds' rates react more predictably. This advocates for better state of these economies, as for Italy and Spain monetary policy surprises mean less.
- amount and impact of surprises detected during the press conference window significantly exceeds that of the press release window
- in the daily time series of government bonds' yields, impulse responses to shocks identified as monetary policy surprise factors are well identified and persistent according to VAR analysis.
- term premia of the longer-term sovereign bonds react to the monetary policy surprises in a similar way as bonds' yields, which shows that term premia are not (locally) constant per country. For the Timing factor, however, this does not hold, meaning that Timing surprises do not affect the term premia. Overall, this advocates for the inclusion of the term premia's dependence on the interest rate level into the monetary transmission model.

5 Conclusions

The aim of this thesis was to study what kind of differences in the euro area countries' reactions to ECB's monetary policy measures can be observed. Therefore, this thesis presents an overview of the recent results about such measures' transmission to the member states' economies, as well as methods routinely used. Particular attention is paid to the measurement approach and methodology of Altavilla et al. (2019).

Most of the literature's econometrical studies are performed using some variant of the vector autoregression (VAR), which remains a default choice for the monetary policy research. Key aspects of this technique are explained in the methodology part of this thesis.

The empirical part follows the procedure of Altavilla et al. (2019) with an updated and expanded data set, covering years 2002-2023. Obtained results are found to be close to the original work's qualitatively and quantitatively, thus proving the method's actuality. This thesis also explores cross-country aspects, which were only briefly touched on in the original.

According to the empirical results, sovereign bonds can be divided into groups with more and less risk. Group with less risk contain German and French bonds, and second group Italian and Spanish. The first group reacts more consistently to the monetary policy measures than the second group, which have more idiosyncratic effects.

Persistence of the monetary policy effects is found to be relatively strong; Finland is found to be close to Germany and France. Overall Finnish economy's reactions are relatively consistent. Unfortunately, I was not able to obtain the high-frequency data for Finnish government bonds. In the light of above mentioned, their most likely reactions to the monetary policy surprises are close to that of Germany and France.

As to the differences among the monetary policy actions, they can be quantitatively classified to the short-term, medium-term and long-term according to their target effect. Such classification is backed by the empirical evidence in the form of surprise factors, detected from the high-frequency trading data. Hence, ECB has versatile working tools to affect the desired time horizon. Stronger economies generally benefit more from the monetary policy measures, especially from the long-term ones such as quantitative easing.

Hypothesis of Gertler and Karadi (2015) about a constant term premium for the government bonds is tested against the same euro area dataset and rejected (as in the original). However, for the certain type of the monetary policy surprises (Timing factor) it could not be rejected.

The main conclusion from all the covered studies is that monetary policy effects are overall quite similar for all euro zone countries, although some heterogeneity in monetary policy transmission is found regularly. Depending on the measurement criteria and the type of the policy action, countries could be grouped and ranked by the degree of their responses. Responses are usually in line with the economic theory, so in this respect ECB serves its purpose well.

Empirical evidence suggests that business cycles synchronization of the euro area has grown since the introduction of the euro. To what extent it is due to the common monetary policy is difficult to assess, but the consensus is, that such convergence weakens during crises and strengthens during economic growth periods. Synchronization should be seen as a desirable outcome, because it decreases incentives to disagree on monetary policy measures and provides a base for the euro area convergence and unity.

Historically, the measurement of the euro area's monetary policy effects is a relatively recent discipline. As more data is gathered and measurement methods' accuracy improves, future research is expected to provide even more precise and meaningful results.

As a final recommendation, I would suggest raising more awareness about all the advantages the euro and the common trade area bring with them, and what a great job ECB is doing towards the goals set to it. Among all the continuous separatist talk, this is as actual as ever. United we stand, divided we fall!

References

Altavilla, Carlo – Brugnolini, Luca – Gürkaynak, Refet S. – Motto, Roberto – Ragusa, Giuseppe (2019) Measuring euro area monetary policy. *Journal of monetary economics*, Vol.108, 162–179.

Angeloni, Ignazio – Ehrmann, Michael – de Grauwe, Paul – Miles, David (2003) Monetary Transmission in the Euro Area: Early Evidence. *Economic policy*, Vol.18 (37), 471–501.

Arčabić, Vladimir – Škrinjarić, Tihana (2021) Sharing is caring: Spillovers and synchronization of business cycles in the European Union. *Economic modelling*, Vol.96, 25–39

Andrade, Philippe – Ferroni, Filippo (2021) Delphic and odyssean monetary policy shocks: Evidence from the euro area. *Journal of monetary economics*, Vol.117, 816–832

Bańbura, Marta – Giannone, Domenico – Reichlin, Lucrezia (2010) Large Bayesian vector auto regressions. *Journal of applied econometrics*, Vol.25 (1), 71–92

Barigozzi, Matteo – Conti, Antonio M. – Luciani, Matteo (2014) Do Euro Area Countries Respond Asymmetrically to the Common Monetary Policy? *Oxford bulletin of economics and statistics*, Vol.76 (5), 693–714.

Bernanke, Ben S. – Gertler, Mark (1995) Inside the Black Box: The Credit Channel of Monetary Policy Transmission. *The Journal of economic perspectives*, Vol.9 (4), 27–48

Bernanke, Ben S. – Boivin, Jean – Eliasz, Piotr (2005) Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach. *The Quarterly journal of economics*, Vol.120 (1), 387–422.

Bernoth, Kerstin – von Hagen, Jürgen – Schuknecht, Ludger (2012) Sovereign risk premiums in the European government bond market. *Journal of international money and finance*, Vol.31 (5), 975–995

Blanchard, Olivier – Amighini, Alessia – Giavazzi, Francesco (2010) *Macroeconomics: a European perspective.* Pearson Education Limited, Essex.

Burgard, Jan Pablo – Neuenkirch, Matthias – Nöckel, Matthias (2019) State-Dependent Transmission of Monetary Policy in the Euro Area. *Journal of money, credit and banking,* Vol.51 (7), 2053–2070

Burriel, Pablo – Galesi, Alessandro (2018) Uncovering the heterogeneous effects of ECB unconventional monetary policies across euro area countries. *European economic review*, Vol.101, 210–229.

Campos, Nauro F. – Fidrmuc, Jarko – Korhonen, Iikka (2019) Business cycle synchronisation and currency unions: A review of the econometric evidence using meta-analysis. *International review of financial analysis*, Vol.61, 274–283

Cavallo, Antonella – Ribba, Antonio (2015) Common macroeconomic shocks and business cycle fluctuations in Euro area countries. *International review of economics & finance*, Vol.38, 377–392

Ciccarelli, Matteo – Maddaloni, Angela – Peydró, José-Luis – Monacelli, Tommaso (2013) Heterogeneous transmission mechanism: monetary policy and financial fragility in the eurozone. *Economic policy*, Vol.28 (75), 459–512

Codogno, Lorenzo – Favero, Carlo – Missale, Alessandro (2003) Yield spreads on EMU government bonds. *Economic policy*, Vol.18 (37), 503–532

Corsetti, Giancarlo – Duarte, Joao B – Mann, Samuel (2022) One Money, Many Markets. *Journal of the European Economic Association*, Vol.20 (1), 513–548

Davies, Glyn (2013) *A history of money*. University of Wales Press, Cardiff.

ECB (2025) *Governing Council.* ECB. <https://www.ecb.europa.eu/ecb/decisions/govc/html/index.en.html>, retrieved 15.4.2025.

ECB (2025) *Tasks.* ECB. <https://www.ecb.europa.eu/ecb/orga/tasks/html/index.en.html>, retrieved 15.4.2025.

ECB (2025) *Transmission mechanism of monetary policy.* ECB. <https://www.ecb.europa.eu/mopo/intro/transmission/html/index.en.html>, retrieved 15.4.2025.

Friedman, Milton (1960) *A program for monetary stability.* Fordham University Press.

Georgiadis, Georgios (2015) Examining asymmetries in the transmission of monetary policy in the euro area: Evidence from a mixed cross-section global VAR model. E*uropean economic review*, Vol.75, 195–215.

Gertler, Mark – Karadi, Peter (2015) Monetary Policy Surprises, Credit Costs, and Economic Activity. *American economic journal. Macroeconomics*, Vol.7 (1), 44–76

Gürkaynak, R.S. – Sack, B. – Swanson, E.T. (2005) Do actions speak louder than words? The response of asset prices to monetary policy actions and statements. *International journal of central banking*, Vol 1(1), 55–93

Guerini, Mattia – Luu, Duc Thi – Napoletano, Mauro (2023) Synchronization patterns in the European Union. *Applied economics*, Vol.55 (18), 2038–2059

Inoue, A. – Rossi, B. (2021) The effects of conventional and unconventional monetary policy: A new approach. *Quantitative Economics*, Vol.12 (4), 1085–1138.

Jarociński, Marek (2010) Responses to monetary policy shocks in the east and the west of Europe: a comparison. *Journal of applied econometrics*, Vol.25 (5), 833–868.

Jarociński, Marek – Karadi, Peter (2020) Deconstructing Monetary Policy Surprises - The Role of Information Shocks. *American economic journal. Macroeconomics*, Vol.12 (2), 1–43

Jorda, Oscar (2005) Estimation and Inference of Impulse Responses by Local Projections. *The American economic review*, Vol.95 (1), 161–182

Kho, Stephen (2025) Deposit market concentration and monetary transmission: Evidence from the euro area. *European economic review*, Vol.173, article 10493

Kilian, Lutz – Lütkepohl, Helmut (2017) *Structural Vector Autoregressive Analysis*. Cambridge University Press.

Mandler, Martin – Scharnagl, Michael – Volz, Ute (2022) Heterogeneity in euro area monetary policy transmission: results from a large multicountry BVAR model. *Journal of money, credit and banking,* Vol.54 (2-3), 627–649

Manganelli, Simone – Wolswijk, Guido (2009) What Drives Spreads in the Euro Area Government Bond Market? *Economic policy,* Vol.24 (58), 191–240

Mertens, Karel – Ravn, Morten O. (2013) The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States. *The American economic review*. Vol.103 (4), 1212–1247

Mishkin, Frederic S. (1995) Symposium on the Monetary Transmission Mechanism. *The Journal of economic perspectives*, Vol.9 (4), 3–10

Moschella, Manuela – Diodati, Nicola M (2020) Does politics drive conflict in central banks' committees? Lifting the veil on the European Central Bank consensus. *European Union politics*, Vol.21 (2), 183–203

Odendahl, Florens – Pagliari, Maria Sole – Penalver, Adrian – Rossi, Barbara – Sestieri, Giulia (2024) Euro area monetary policy effects. Does the shape of the yield curve matter? *Journal of monetary economics*, Vol.147, article 103617.

Peersman, Gert – Smets, Frank (2001) The Monetary Transmission Mechanism in the Euro Area: More Evidence from VAR Analysis. *ECB Working Paper 91*

Pesaran, M. Hashem – Schuermann, Til – Weiner, Scott M (2004) Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model. *Journal of business & economic statistics*, Vol.22 (2), 129–162

Rigobon, Roberto – Sack, Brian (2003) Measuring The Reaction of Monetary Policy to the Stock Market. *The Quarterly journal of economics*. Vol.118 (2), 639–669

Romer, David (2019) *Advanced macroeconomics*. McGraw-Hill, New York

Stock, James H. – Watson, Mark W. (2001) Vector Autoregressions. *The Journal of economic perspectives,* Vol.15 (4), 101–115

Stock, James H. – Watson, Mark W. (2012) Disentangling the Channels of the 2007-09 Recession. *Brookings papers on economic activity*, Vol.2012(1), 81–156

Swanson, Eric T. (2021) Measuring the effects of federal reserve forward guidance and asset purchases on financial markets. *Journal of monetary economics*, Vol.118, 32–53

Walsh, Carl E. (2017) *Monetary theory and policy*. MIT Press, Cambridge

Appendices

Appendix 1 Factor decomposition

Test for number of factors for updated data (Wald statistics and p-values)

Table 5 Test for number of factors for updated data (Wald statistics and p-values)

	Press release window		Press conference window	
H_0	Pre-QE	Full sample	Pre-QE	Full sample
0 factors	46.20 (0.001)	40.95 (0.006)	105.50 (0.000)	127.11 (0.000)
1 factor	**18.77** **(0.174)**	**24.00** **(0.046)**	33.73 (0.002)	47.32 (0.000)
2 factors	8.37 (0.398)	13.01 (0.112)	14.87 (0.062)	24.94 (0.002)
3 factors	2.00 (0.572)	3.21 (0.360)	**3.32** **(0.345)**	**6.42** **(0.093)**

Null hypothesis is number of factors present in the first column, other cells are Wald statistics for alternative hypothesis that number of factors is greater. Test shows similar results to that of the original paper. P-value for 1 factor in press release's window for full sample is slightly below 0.05, but I do not believe this to be a sufficient reason for increasing press release's number of factors to 2.

Relative contribution of factors in explaining policy surprises, full sample (variance decomposition) is shown in the table 6.

Table 6 Relative contribution of factors in explaining policy surprises, full sample (variance decomposition)

	1-month	3-month	6-month	1-year	2-year	5-year	10-year	SD Factor
Press release								
Target	99.3	78.2	65.7	29.6	7.4	1.2	0.3	2.7
Residual	0.7	21.8	34.3	70.4	92.6	98.8	99.7	NA
SD OIS rel.	2.7	2.4	2.1	2.2	2.3	2.2	1.7	NA
Press conference								
Timing	52.5	84.5	63.1	41.5	22.6	11.3	7.2	2.1
Forward Guidance	0.0	10.6	35.0	57.1	74.2	65.3	34.4	3.6
QE	0.0	0.0	0.0	0.2	2.4	21.1	55.7	2.1
Residual	47.5	4.9	1.9	1.1	0.8	2.3	2.8	NA
SD OIS conf.	1.0	1.9	2.6	3.7	4.2	4.1	2.9	NA

Results are still close to the original paper's, although some percentages differ significantly, especially, Target's explanatory power drops faster for bonds with longer maturity.

Appendix 2 Financial VAR, updated data

VAR performed on 2-year OIS, STOXX50E, ILS2Y, and EUR/USD exchange rate. Identification by external variable, which is a factor value, one at a time (figure 10).

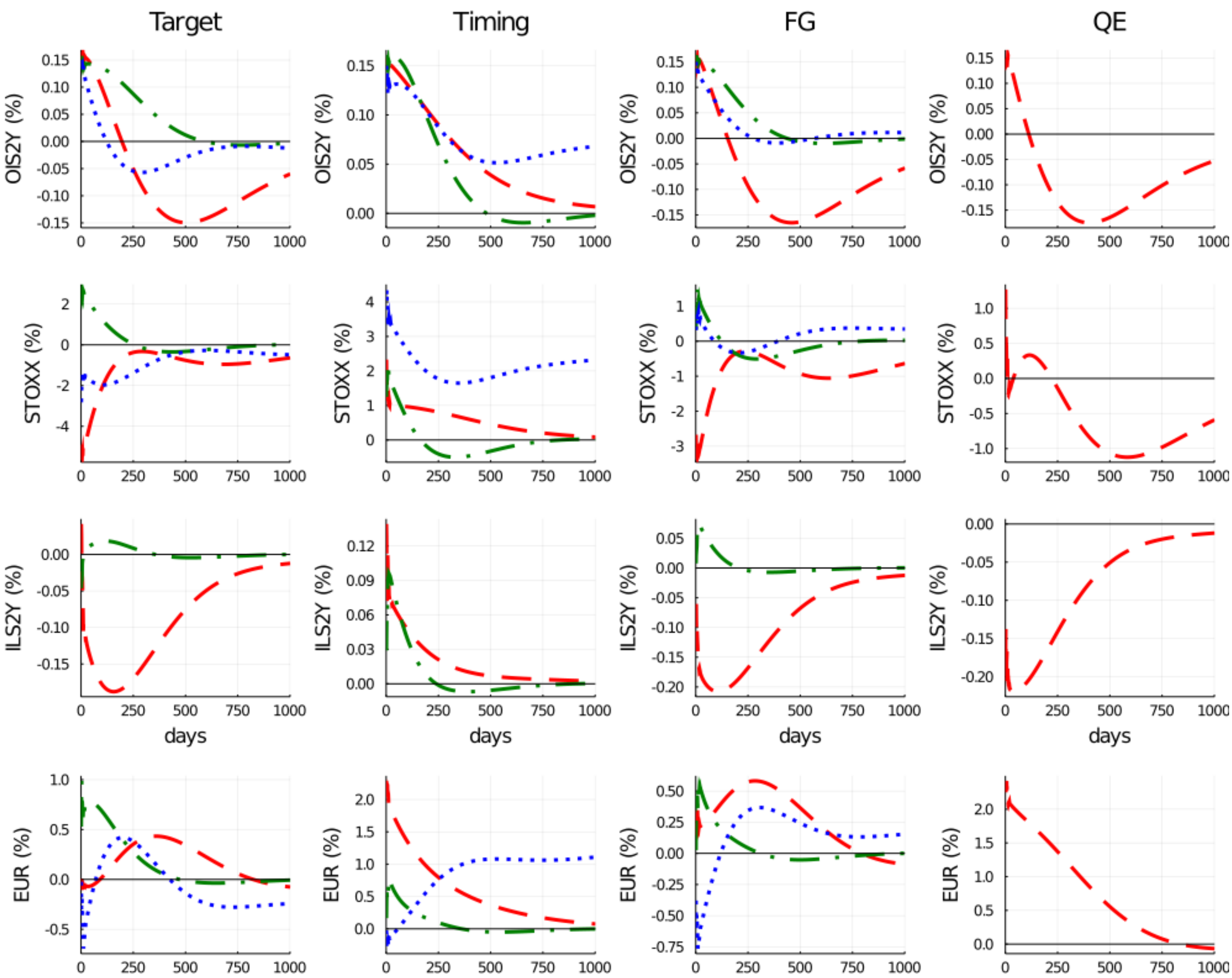

Figure 10 Daily VAR of OIS2Y, EUROSTOXX50, ILS2Y and EUR/USD exchange rate

Red dashed line represents IRFs in 2014-2023 period. They became somewhat closer to pre-crisis IRFs (green dash-dot line) than in the original paper.

Appendix 3 Persistence of effects on government bond rates

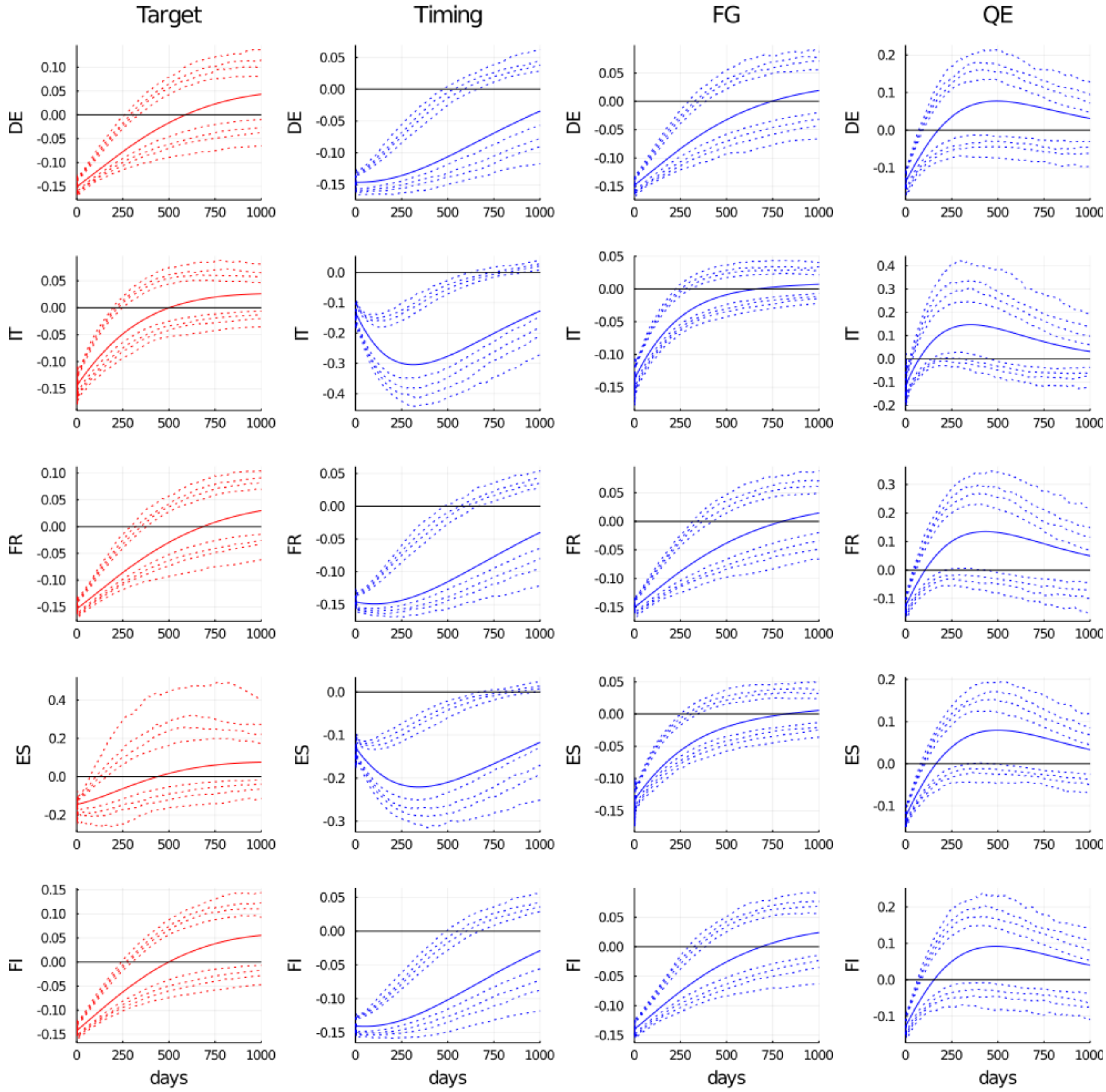

Figure 11 IRF of 2-year sovereign bond rates

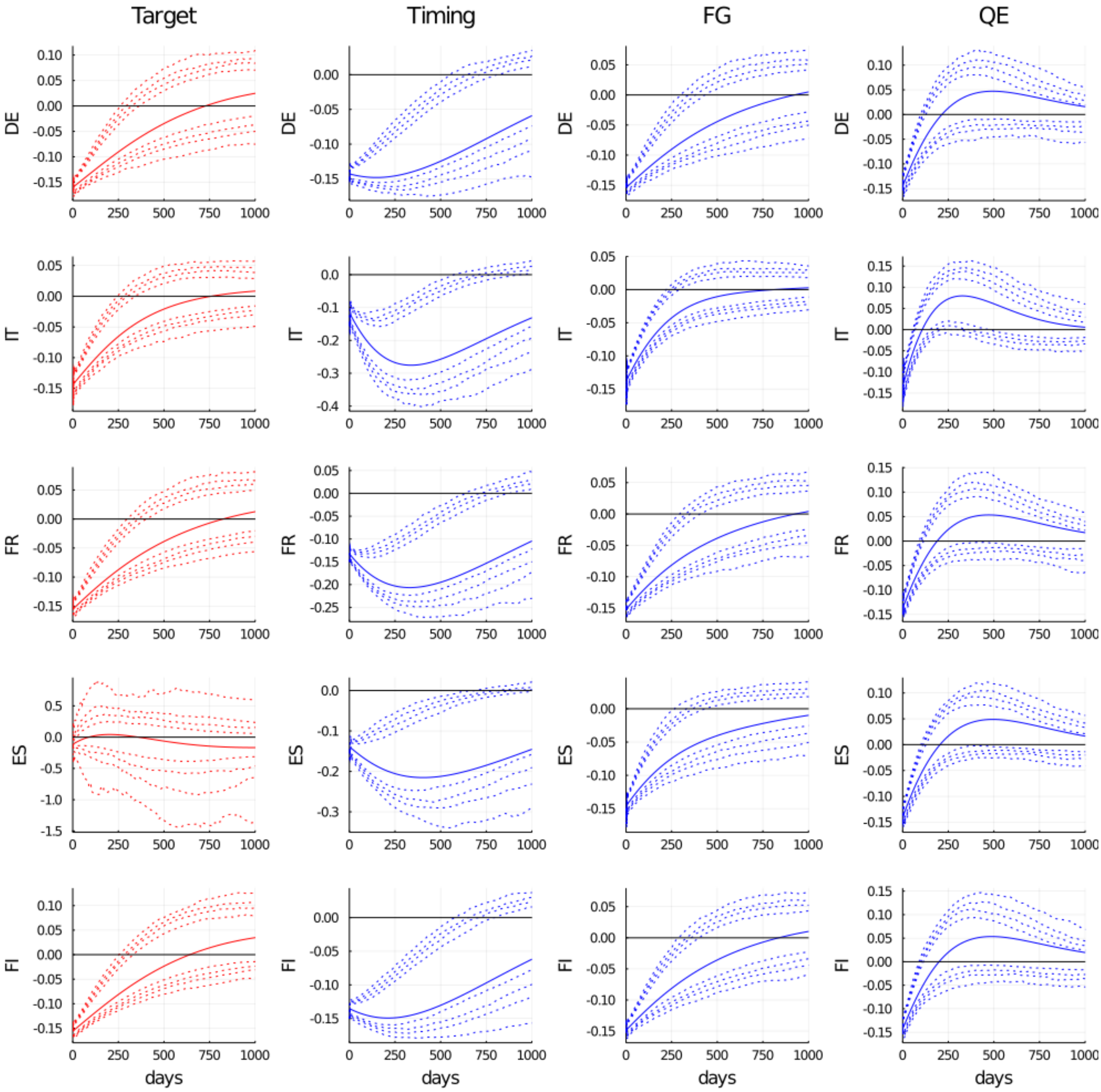

Figure 12 IRF of 5-year sovereign bond rates