Szabó Eszter

The Transmission of Negative Interest Rates in the Euro Area

Department of World Economy

Supervisor:
Kutasi Gábor, PhD, Dr. habil

CORVINUS
UNIVERSITY
of BUDAPEST

Doctoral School of International Relations
and Political Science

The Transmission of Negative Interest Rates in the Euro Area

Doctoral Dissertation

Szabó Eszter

Budapest
2024

Table of contents

List of figures

List of tables

List of abbreviations

CPI	Consumer Price Index
CUSUM	Cumulative Sum
DFR	Deposit facility rate
DSGE	Dynamic stochastic general equilibrium
ECB	European Central Bank
ECM	Error correction model
ELB	Effective lower bound
FG	Forward guidance
GDP	Gross domestic product
HANK	Heterogeneous Agent New Keynesian model
IMF	International Monetary Fund
IRF	Impulse response function
IT	Inflation targeting
MNB	Magyar Nemzeti Bank (Central Bank of Hungary)
NIRP	Negative interest rate policy
NCM	New Consensus Macroeconomics
NK	New Keynesian
OCA	Optimum currency area
OECD	Organisation for Economic Co-operation and Development
QE	Quantitative easing
QTM	Quantity theory of money
SNB	Swiss National Bank
UK	United Kingdom
US	United States of America
VAR	Vector autoregression
VECM	Vector error correction model
ZIRP	Zero interest rate policy
ZLB	Zero lower bound

Acknowledgements

I would like to acknowledge the work of my supervisor, Gábor Kutasi, who provided the necessary guidance and help throughout the years. I also appreciate that he always let me progress at my own pace.

I am grateful to the referees of my draft thesis, several teachers of the Corvinus University and some colleagues for their useful comments and advice. I am also very thankful for all the administrative help that I have received from the staff of the university.

Finally, I would like to thank my family and friends who have always supported, encouraged and helped me through difficult times.

I. Introduction

The monetary transmission mechanism is a frequently discussed area of economic research. It is crucial to understand how a central bank can influence the development of macroeconomic variables, such as inflation or output. In the last decades, several channels of monetary transmission have been identified and studied. Although monetary policy can affect the economy in many ways, its most important tool before the 2008 global financial crisis was traditional interest rate setting. However, the crisis quickly highlighted the limits of conventional monetary policy, when interest rates approached zero. Central banks of several developed countries transformed their toolkits, and unconventional measures usually seemed to be appropriate to handle the most severe effects of the financial crisis. However, mainly in Europe, economic growth remained fragile, deflation proved to be a major difficulty; furthermore, debt accelerated quickly and then stabilized at a high level.

One of the most highly debated new tools of monetary policy has been definitely the negative interest rate policy (NIRP). The topic naturally received a large amount of attention from researchers and decision-makers as well. After the global financial crisis, central banks lowered the interest rates to support the economic recovery. In several developed countries, interest rates quickly reached the zero lower bound (ZLB). In spite of the extremely low rates, economic growth did not rebound, or remained fragile, in many cases. The central banks of the Euro Area, Denmark, Japan, Sweden and Switzerland, reduced their policy rates below zero to provide further stimulus to the economy[1]. However, this unprecedented move yielded mixed results. Research about the effectiveness of negative policy rates is contradictory. The most important topics regarding NIRP are the transmission of negative rates and their impacts on the banking sector. A major concern of monetary transmission at negative nominal interest rates was the assumption that deposit rates of commercial banks cannot fall below zero, since this move would result in the withdrawal of money from banks. Furthermore, negative lending rates also seemed unreasonable. Although some commercial banks experimented with negative interest rates (Arnold, 2019; Martin, 2019; Wass, 2020), these were rather the exemptions than the rule.

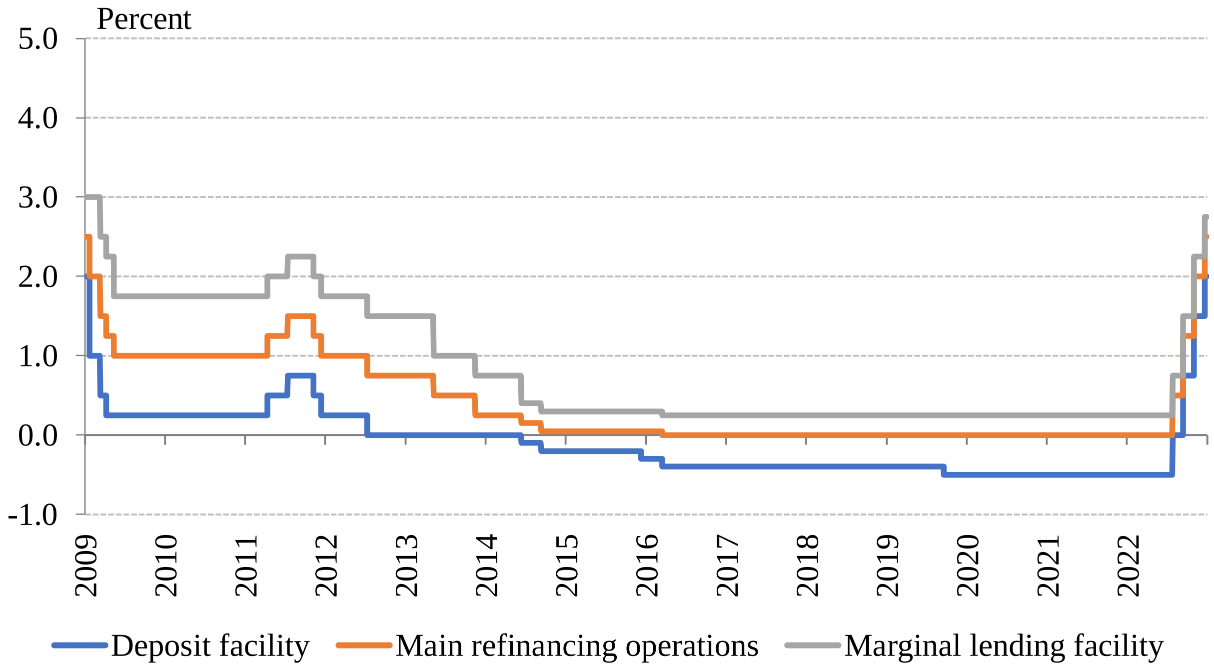
In June 2014 the European Central Bank cut its deposit facility rate (DFR) below zero (*Figure 1*) and it kept the DFR in negative territory until July 2022. The eight years long era of negative interest rates came to an end in the middle of 2022 with the first rate hike, which was

---

[1] In Denmark and Switzerland, an important motivation was the avoidance of the sharp appreciation of the domestic currency.

necessary for curbing down rising inflation in the Euro Area. The closure of NIRP provides an opportunity to assess the performance of negative nominal interest rates and to draw conclusions.

Figure 1: Key interest rates of the European Central Bank



Source: Constructed by the author based on ECB data

My research focuses on the interest rate channel of the monetary transmission mechanism. I examine how this channel works in Eurozone member states if interest rates become negative. My dissertation is structured as follows. The next section presents the aim and relevance of the research and introduces the hypotheses. The third part reviews the theoretical and empirical literature related to the topic. The methodology and the results of the analysis are presented in the fourth section. Finally, a conclusion of the research is outlined.

II. Aim and relevance of the research

In 2022, the increase in inflation brought an end to the era of negative nominal interest rates in the Euro Area. However, the exit was not easy. The decision to end the period of negative nominal interest rates was preceded by a long discussion about the nature of inflation (whether it was temporary or permanent). By the time the ECB decided to raise interest rates, the annual inflation rate in the Euro Area was approaching 9 percent (Eurostat, 2022b). In order to maintain credibility, central banks had to take action.

My research focuses on the interest rate channel of the monetary transmission mechanism. I study how this channel works in Eurozone countries when interest rates become negative. Although several channels through which monetary policy can affect the real economy have been identified over the past two decades, I believe that the interest rate channel is still an important one, if it works properly. After all, the negative interest rate policy is an interest rate instrument with which the ECB wanted to influence, among other things, commercial bank interest rates (Boucinha et al., 2020).

The major goal of my research is to explore how negative rates are transmitted into commercial bank rates by using relatively simple econometric models. It is important to understand how negative interest rates affect the economy which was studied by several researchers with complex macroeconomic models. I concentrate on a smaller part of this process, the first step of the monetary transmission. I narrowed down the focus to the Euro Area and I am also interested in the possible differences among member states. In relation to negative interest rates, researchers usually examine all countries that adopted NIRP, the Eurozone (or some larger economy, such as Germany) and the usage of bank level data is also popular. Extending the analysis to all member states and the reliance on simpler econometric tools may provide some new information.

2.1. Research questions and hypotheses

I have formulated the following three research questions and hypotheses for my research:

Research question 1: How does monetary transmission through the interest rate channel change in Euro Area countries if the policy rate becomes negative?

- **Hypothesis 1:** Monetary transmission through the interest rate channel weakens in Euro Area countries if the policy rate becomes negative.

After reviewing the theoretical and empirical literature I assume that the adoption of a negative interest rate policy alters the functioning of the interest rate channel. An interest rate cut in negative territory may have different effects than in positive territory. I also assume that the interest rate channel of the transmission mechanism becomes less effective, when interest rates are negative. Experience shows that commercial banks have been quite reluctant to pass on negative interest rates to their clients, which suggests that the influence of policy rates on commercial bank interest rates may have diminished.

Research question 2: Does negative interest rate policy have similar effects on the interest rate transmission across Euro Area countries?

- **Hypothesis 2:** The negative interest rate policy has different effects on the interest rate transmission in Euro Area countries.

This hypothesis is based on the assumption that there are differences in the monetary policy transmission mechanism, macroeconomic processes, the financial sector and other factors across Euro Area member states, and that the impact of negative interest rates may therefore vary.

Research question 3: How does the negative interest rate policy affect monetary transmission through the interest rate channel in the corporate and in the household sectors?

- **Hypothesis 3:** The monetary transmission mechanism is less effective in the household sector than in the corporate sector when the policy rate is negative.

I suppose that the monetary transmission mechanism is less effective in the household sector than in the corporate sector in a negative interest rate environment. Commercial banks are less likely to pass on negative interest rates to households, because in this segment cash can be a good alternative to negative interest rates on bank deposits. If deposit rates cannot be lowered, profitability considerations are likely to prevent lending rates from being lowered. However, the composition of a bank's assets and liabilities does matter, since the evolution of deposit and lending rates affects net interest income.

Another important factor is that the maturity of loans differs between the household and corporate sectors. As Yun & Cho (2022) write, the impact of monetary policy on corporate loans is more significant than on household loans. Because of the shorter maturity, a large share of corporate loans is refinanced more frequently than household loans, which have longer maturities.

Finally, household loans can be subsidized to protect households from negative economic effects. Subsidies can serve important economic policy objectives and can be justified, but they weaken the transmission mechanism of monetary policy.

I test the hypotheses by estimating two types of error correction models (ECM) and vector autoregressive models (VAR). The approach is discussed in detail in the methodological part of the dissertation.

III. Literature review

The literature review consists of four parts. In the first one, the most important money and interest rate theories are presented which influenced economic thinking about monetary policy. The next section introduces the monetary transmission mechanism from theoretical and empirical point view, the functioning of the different channels is described and several studies are reviewed. The third part discusses the theoretical and empirical aspects of negative interest rates, while the last section focuses on the transmission in the Euro Area.

3.1. Money and interest rate theories

In the last decades, especially after the global financial crisis, monetary policy has received more and more attention. However, it was not entirely obvious earlier how monetary policy can affect the real economy. Furthermore, there is no consensus between different schools of economic theory whether it influences real variables at all. In this section I review the most important theories about the relationship between monetary policy and the real economy. The purpose of this part of the literature review is to provide an overview of the evolution of thinking about money, interest rates and monetary policy. The theoretical framework of the dissertation – the monetary transmission mechanism – is presented in the next section. The analysis focuses on the interest rate channel of transmission, which is based on Keynesian grounds. However, I have found it important to show the development of economic thought, as some theories have had a strong influence on monetary policy decision-making.

3.1.1. Classical theory

The cornerstone of 19th century classical economics that describes the mechanism of monetary transmission is the quantity theory of money (QTM). According to the theory, there is a direct link between the general price level and the money supply in an economy. The QTM originally dates back to the 16th century when increases in prices were first noted following the import of monetary metals (Humphrey, 1974). According to the classical view of monetary transmission, the money supply does not affect the real economy; it cannot alter the level of real variables such as output, so money is neutral.

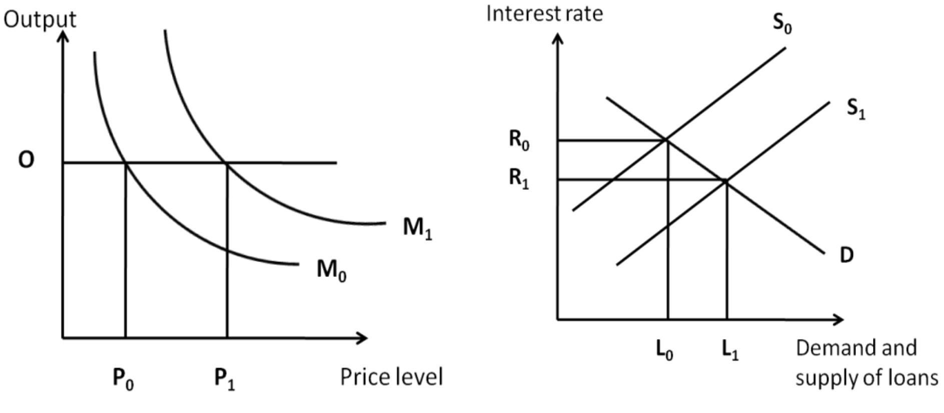
The quantity theory of money can be written with the equation of exchange formulated by Simon Newcomb (1885) and popularized by Irving Fisher (1911):

$$MV = PT \qquad (1)$$

where M is the stock of money, V is the velocity of circulation of money, P is the price level and T is the volume of market transactions. If the supply of money changes, the price level will vary in the same proportion. This proportionality arises from the assumption that people want to hold a constant amount of real cash balances, since they look at the purchasing power and not the money value of cash balances. So the price level needs to vary in exact proportion to changes in the nominal money supply in order to keep the real balances intact (Humphrey, 1974).

The classical theory identifies two channels through which the changes of the money supply are transmitted to the price level: direct expenditure and indirect interest rate mechanisms (*Figure 2)*. Through the former channel, an increase in the money supply raises real cash balances above the desired level; cash holders will have more money than they want to hold, which leads to a rise in spending on goods. However, if the economy operates at full capacity, an increase in spending puts an upward pressure on prices. Prices rise until real cash balances reach the desired level and the equilibrium is restored. Meanwhile, the indirect mechanism operates through a prior effect on the interest rate. An increase in the money supply leads to a fall in the interest rate which stimulates investments, and this exerts an upward pressure on the price level (Humphrey, 1974).

Figure 2: The direct and indirect channels of monetary transmission

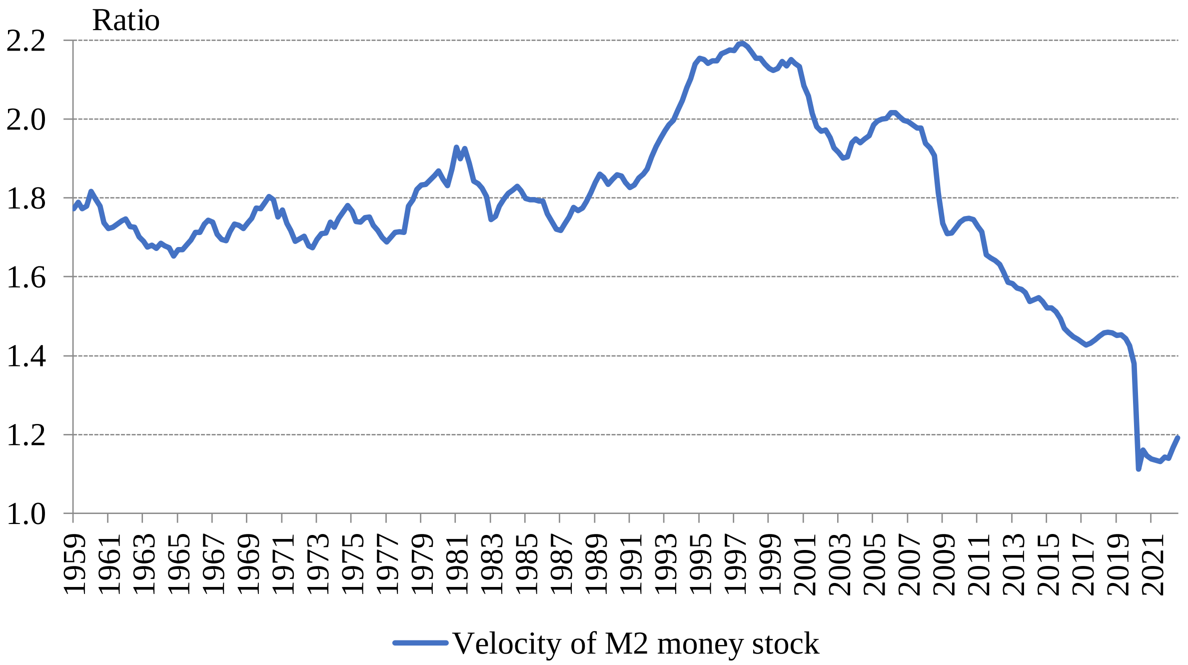


Source: Constructed by the author

An important assumption of the theory is that the economy operates at its full productive potential (Humphrey, 1974). In the years before the coronavirus pandemic, more countries have been quite close to this state: unemployment was at historically low levels and capacity utilization was also at a record high. Nevertheless, this usually was not the case in the past decades. The economy more often operates above or below its potential level. If full employment does not prevail, a raise in the money supply can have an effect on spending; a monetary expansion may lead to an increase in output. This was exactly the case in more countries after the global financial crisis when central banks reduced interest rates and injected liquidity into the economy. As credit constraints eased, consumption and investment started to rise. Consequently, money is not neutral, at least when the economy is not at full employment.

The quantity theory of money presumes that the velocity of money is stable (Humphrey, 1974). However, data shows that this assumption does not hold; the velocity of money is not constant over time *(Figure 3)*. If the velocity is unstable, it may strengthen or weaken the effects of a change in the supply of money. Accordingly, the effects of a monetary expansion are not certain. The central bank is not able to control the velocity of the circulation of money. It depends on the expectations and the decisions of economic agents. If inflationary expectations are higher, the velocity increases, while disinflationary or deflationary expectations lead to lower velocity (Mueller, 2018).

Figure 3: Velocity of M2 money stock in the United States



Source: Constructed by the author based on Federal Reserve Bank of St. Louis data

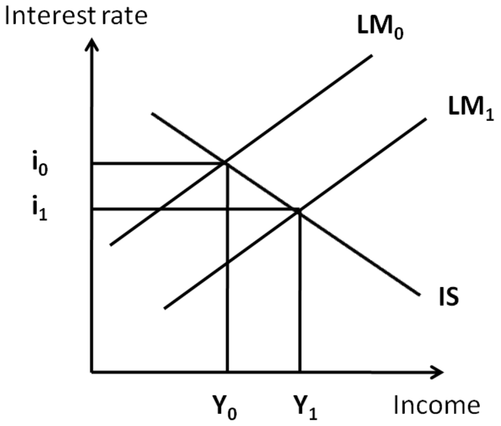
It is not difficult to realize that the assumptions of QTM are ambiguous and the theory contains serious oversimplifications which make it unsuitable to explain recent developments in the field of monetary policy.

3.1.2. Keynesian theory

Keynesian monetary theory mainly focuses on the short-run effects of monetary policy, particularly on the rigidities arising from the assumption that prices are fixed in the short-term. A state of equilibrium does not require full employment. Money is not neutral, so the changes of the money supply can have permanent effects on interest rates and real variables. Changes in the money supply are transmitted into the real economy through interest rates indirectly (Jahan et al., 2014).

According to the Keynesian ISLM model, an increase in the supply of money shifts the LM curve right (*Figure 4)*. Consequently, the real interest rate falls, which lowers the cost of capital, resulting in a raise in investment spending and thereby output rises, provided that the price level remains unchanged (Jahan et al., 2014).

Figure 4: The effect of a money supply change in the ISLM model

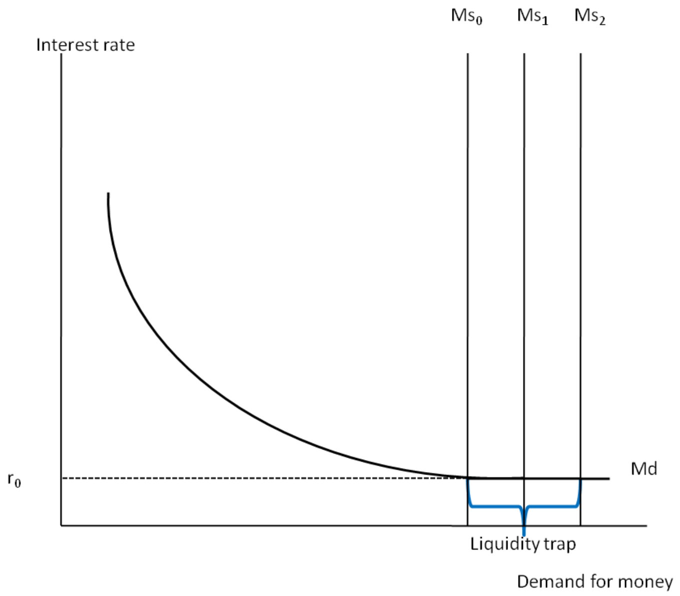


Source: Constructed by the author based on Jahan et al. (2014)

The non-neutrality of money in Keynesian theory depends upon two conditions. At first, the economy is not in a situation of a liquidity trap because, in this case, the increase of the money supply is simply added to idle balances and does not influence the real sector. Secondly, the changes of the money supply are transmitted to real variables through the interest rate, so if expenditures are not interest rate sensitive, then money is neutral (Jahan et al., 2014).

Keynesian monetary theory resolves the full employment and the neutral money assumptions, which bring us closer to reality. However, if the economy is in a liquidity trap, money is neutral and monetary expansion can be ineffective. Arias and Wen (2014) point out that in a liquidity trap, both conventional and unconventional tools of monetary policy can fail. If the demand for money increases more than proportionally to the change in the supply of money, the price level falls in order to restore equilibrium between supply and demand. The asset purchase programs of central banks put a downward pressure on interest rates. This leads to a raise in aggregate demand for money, since investors are holding cash rather than investing it when the nominal interest rate is zero.

Figure 5: Liquidity trap



Source: Constructed by the author based on Jahan et al. (2014)

The balance sheets of major central banks (e.g. Federal Reserve, European Central Bank, Bank of Japan) more than doubled since the global financial crisis. In spite of the unprecedented monetary expansion (through conventional and unconventional measures) aggregate demand remained subdued in more advanced economies. The Euro Area and Japan could have been in a liquidity trap for years (Udland, 2016; Sau, 2018; Akram, 2016; Homburg, 2017) in which situation money is neutral and monetary policy is ineffective (*Figure 5*).

3.1.3. Monetarist theory

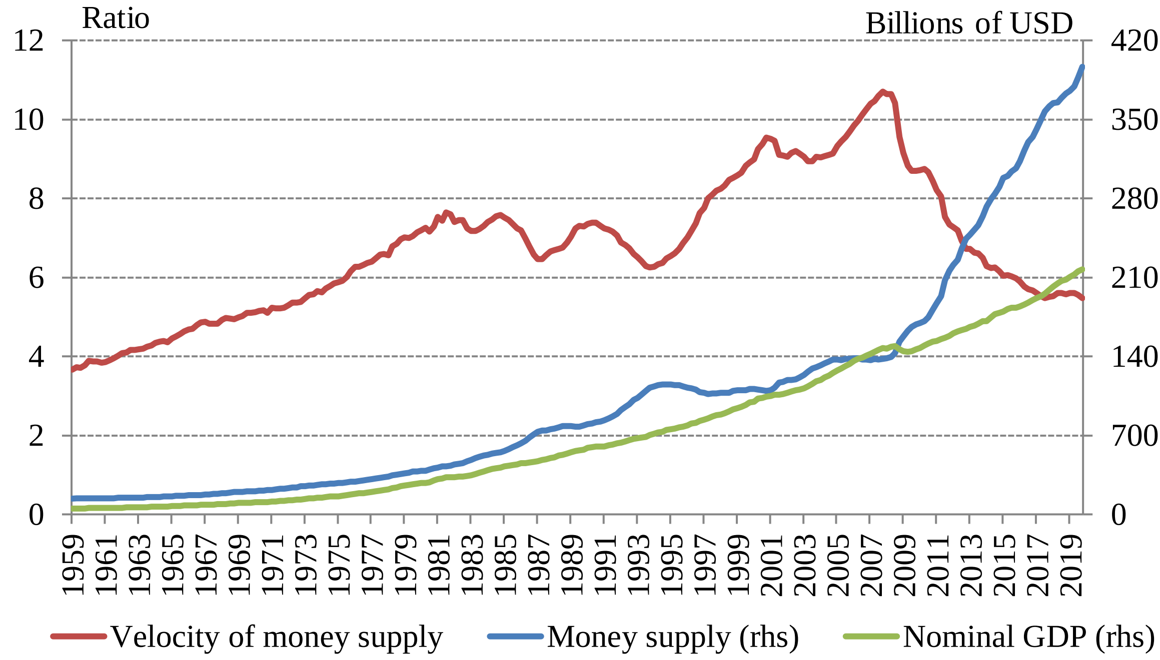
The monetarists also lay claim to the non-neutrality of money in the short run; however, they criticize the Keynesian view of the transmission mechanism because they believe that monetary policy can affect the real economy, not only through the interest rates, but through financial assets, durable goods and especially equities and real estate. The changes in asset prices have wealth effects which influence, through spending, the level of output and employment (Ireland, 2010).

A cornerstone of the monetarist theory was provided by Milton Friedman, with the restatement of the classical quantity theory of money. According to Friedman, the QTM is a theory of the demand for money. Money is not only a medium of exchange, but it functions as an asset as well. The demand for money is determined by total wealth, which is held in various forms, the division of wealth between human and non-human forms, the expected return on these assets, and other variables such as income. Wealth can be held in five different forms: money, bonds, equities, physical non-human goods and human capital. Meanwhile, the money supply is mainly determined by the interest rate and nominal income. The money supply is quite unstable, it changes due to the actions of monetary authorities, while the demand for money is relatively stable according to the theory (Friedman, 1987).

If the economy operates at less than full capacity, an increase in the money supply results a raise in output, since the rise of the money supply leads to higher spending, which raises income (Friedman, 1987). Although, according to the monetarist theory money is neutral in the long run, as an implication of rational behavior, adjustment takes time. Relative prices and output respond to monetary shocks before those impulses are fully absorbed (Meltzer, 1995).

A major element of monetarist theory is that the central bank should target the growth rate of the money supply in order to control inflation (Vaggi & Groenewegen, 2016). However, the events of the 1980s demonstrated the shortcomings of this policy. The positive relationship between the money supply and nominal GDP depends on the velocity of money. If the velocity is stable and predictable, nominal GDP increases in line with the growth of the money supply. In the 1980s and 1990s, the velocity of money became unstable and unpredictable (*Figure 6*), so the link between the supply of money and nominal GDP fell apart (Jahan & Papageorgiou, 2014).

Figure 6: M1 money supply, the velocity of M1 and nominal GDP in the United States



Note: Seasonally adjusted data. GDP is reduced by a factor of 10 to fit the chart.
Source: Constructed by the author based on Federal Reserve Bank of St. Louis data

In 1979 the Federal Reserve adopted a new policy – which had common features with the recommendations of monetarists – to bring down inflation from double-digit levels. It basically started to target the growth rate of M1. Although inflation dropped, the economy fell into a recession. The representatives of the theory argued that the policy was not monetarist in its design. Nevertheless, it exposed the undesirability of money growth targets and the difficulties of controlling the supply of money, and contributed to the invalidating of the monetarist theory (McCallum, 2004). Pilkington (2014) also challenges the ability of the central bank to control the supply of money. He states that it rather depends on the demand for money, which is determined by spending, and investment decisions of economic agents.

3.1.4. New classical theory

The new classical theory holds the view that money is neutral even in the short run, since economic agents have rational expectations. If the money supply changes, they adjust their expectations accordingly. The effect of money on prices is explained by the quantity theory of money, so changes of the money supply do not influence real variables, only prices (Niehans, 1987).

According to new classical theory, the only way for monetary policy to affect the level of output is if it acts by surprise, since an unexpected change cannot influence the expectations of agents. In this case, monetary policy can have an effect on real variables in the short run.

Even before the global financial crisis, monetary policy decision-making started to become more and more transparent. Central banks intend to influence expectations with clear communication. The role of forward guidance (FG, the orientation of markets) has extremely appreciated after the crisis. The inflation targeting framework also requires clear communication and transparency from the monetary authority, therefore I believe that in such an environment, it is usually not worth risking credibility by acting by surprise to achieve short-term results.

The assumption of rational expectations is also worth discussion. Although, the rational expectations hypothesis became an important element of macroeconomic theory, there are arguments disproving it. Frömmel (2017) claims that expectations can easily be adaptive and rather backward-looking instead of forward-looking, since agents do not necessarily search for all available information. Furthermore, learning can be slow and imperfect.

3.1.5. New Keynesian theory

New Keynesian (NK) theory has made a considerable impact on economics and the analyses of monetary policy. The theory is built on the assumption of nominal price and wage rigidities which makes it possible for monetary policy to have an effect on real variables in the short run. The major analytical framework of New Keynesian economics is the dynamic stochastic general equilibrium (DSGE) model. The basic framework consists of an Euler equation, a New Keynesian Phillips curve and a Taylor rule, involving three variables: output y_t, inflation π_t and the short-term nominal interest rate i_t (Ireland, 2010; Rupert & Šustek, 2018).

$$y_t = E_t y_{t+1} - \sigma(i_t - E_t \pi_{t+1}) \qquad (2)$$

the expectational IS curve (*Equation 2*) links output in period t to its expected value in $t+1$ and to the ex ante real interest rate, computed by subtracting the expected rate of inflation, π_{t+1} from the nominal interest rate, i_t (Ireland, 2010).

$$\pi_t = \beta E_t \pi_{t+1} + \gamma y_t \qquad (3)$$

the New Keynesian Phillips curve (*Equation 3*) describes the optimal behavior of monopolistically competitive firms that either face explicit costs of nominal price adjustment, or set their nominal prices in randomly staggered fashion (Ireland, 2010). The former one was suggested by Rotemberg (1982), while the latter one by Calvo (1983).

$$i_t = \alpha\pi_t + \psi y_t \tag{4}$$

finally, the Taylor rule for monetary policy (*Equation 4*) (Taylor, 1993), which outlines central bank behavior. In response to movements in inflation and output, the central bank systematically adjusts the short-term nominal interest rate (Ireland, 2010).

In the basic New Keynesian model, monetary policy influences the real economy through the traditional Keynesian interest rate channel. A monetary tightening (in the form of a shock to the Taylor rule) raises the short-term nominal interest rate, since nominal prices are sticky (due to costly or staggered price setting); the real interest rate increases too. The higher rate of interest leads to a reduction of spending by households, as summarized by the IS curve. Finally, through the Phillips curve, the decrease in output puts downward pressure on inflation, which adjusts only gradually after the shock (Ireland, 2010).

Obviously, the NK theory has its own shortfalls. It also assumes rational expectations which – as was mentioned above – may not be realistic. However, this assumption can be resolved; Woodford (2013) reviews a variety of alternative approaches. The New Keynesian theory received a great amount of criticism regarding the failure of models built on it to predict the global financial crisis, its assumptions of perfect information, or an infinitely-lived representative household. Nevertheless, as Galí (2018) points out, various extensions have been developed in order to incorporate new assumptions and phenomena, and it remained the dominant paradigm of macroeconomic thinking.

3.1.6. New Consensus Macroeconomics

In the 1980s, a New Consensus in Macroeconomics (NCM) emerged which built heavily on New Keynesian economics (Arestis, 2009; Nachane, 2013). The NCM incorporated the micro-foundations of Keynesian sticky prices and wages with optimization under rational expectations. With the efficient market hypothesis and the rational expectations hypothesis, it also provided an intellectual basis for the wave of financial liberalization in the 1980s (Nachane, 2013).

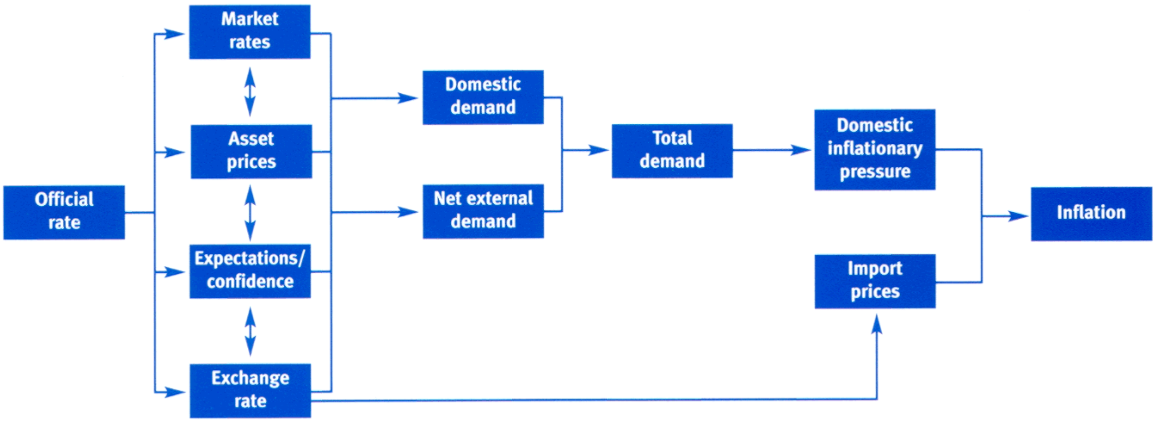
The New Consensus in Macroeconomics became highly influential, especially in the field of monetary policy (Arestis, 2009). However, the global financial crisis pointed out its various shortcomings. The NCM could not predict the extent and the severity of the crisis and the solutions based on its framework were not successful (Nachane, 2013). After the crisis, the focus was shifted towards fiscal policy.

3.2. The monetary transmission mechanism

The monetary transmission mechanism is the process through which monetary policy affects the real economy. The development of the macroeconomic variables is determined by the decisions of economic agents. By changing the policy rate the central bank is able to affect these decisions, and through that the aggregate demand and inflation (MNB, 2012).

As *Figure 7* shows the effects of monetary decisions first appear in financial markets. Market interest rates, asset prices, the exchange rate and expectations react most quickly. This is followed by an adjustment in the product market, and aggregate demand changes. In response to the change of demand, producers alter the quantity and the prices of their products, so monetary policy influences output and inflation (MNB, 2012).

Figure 7: The monetary transmission mechanism



Source: Constructed by the author based on George et al. (1999)

3.2.1. Inflation targeting

From the 1990s, several central banks adopted an inflation targeting regime both in developed countries and in emerging economies. In this system, the monetary authority publicly announces medium-term numerical targets for inflation with a commitment to achieve these targets (Mishkin & Posen, 1997). So, the primary objective of the central bank is to reach and maintain price stability. A vast amount of literature is available on monetary regimes but I do not intend to go into detail regarding this topic. However, the actions of monetary policy – in the case of my research the adoption of the negative interest rate policy – need to be interpreted within the inflation targeting framework, so this section briefly introduces the IT system.

As Croce & Khan (2000) write, high inflation eventually leads to slower economic growth, since it influences the decisions of economic agents about investment, saving and production. During the 1980s and 1990s it became evident that an activist monetary policy that seeks to support output and reduce unemployment beyond their sustainable level results in higher inflation. Meanwhile it does not lead to higher output or lower unemployment (Mishkin & Posen, 1997). As for the nominal anchor, an exchange rate rule strictly limits the actions of the monetary authority, because it cannot react to domestic or external shocks, monetary policy is directed only at the exchange rate. In countries with a flexible exchange rate regime, monetary aggregates became the medium-term target for monetary policy. In this system, the central bank aims to control monetary aggregates, which are considered the most important determinants of inflation in the long run (Croce & Khan, 2000).

Monetary targeting and inflation targeting may result in similar central bank behavior (von Hagen, 1998), however, in the 1980s, monetary targeting brought unsatisfactory results. The demand for money became unstable and it turned out that money and inflation are not sufficiently correlated in the short run. These experiences in several OECD countries led to the adoption of the inflation targeting system (Croce & Khan, 2000).

Mishkin & Schmidt-Hebbel (2001) review the first decade of experiences with inflation targeting regimes in the world. They come to the conclusion that IT systems proved to be quite successful in controlling inflation and improving the performance of the economy. The experiences show that the adoption of an inflation targeting regime supports transparency and accountability of the central bank and it also enhances communication. The 1997 Asian financial crisis and the 1999-2000 oil price shock tested the IT system in some affected countries and it proved to be resistant. The volatility of output declined both in advanced and emerging economies that had started to target inflation. There is also some evidence that an IT system has positive effects on guiding inflation expectations. However, the authors also state that unresolved questions remain about how to best operate an inflation targeting framework. The major issues are related to the target horizon, the width of the target range, escape clauses and the choice of core inflation targets.

About 10 years later the performance of the inflation targeting framework was assessed by Walsh (2009). In case of advanced economies, the experiences are similar among inflation targeting and non-targeting countries. However, an IT system improved macroeconomic performance among developing countries. It delivered lower inflation and more stable real economy. An important criticism regarding inflation targeting regimes was also denied by the paper of Walsh. According to the critics, inflation targeting central banks neglect the real economy. However, evidence shows that real economic instability did not worsen under an IT framework. Monetary authorities practiced flexible targeting, besides controlling inflation, they also paid attention to the stability of the real economy. Overall, the experiences regarding inflation targeting are positive.

The 2008 global financial crisis posed another challenge to inflation targeting. As Woodford (2012) writes, many argued that the IT framework has to be reconsidered in light of the crisis, since monetary policy neglected financial stability. After the crisis, central banks started to pay more attention to the financial sector worldwide, macroprudential policy and supervision were strengthened but inflation continued to be the primary nominal anchor of monetary policy in many countries.

According to the latest annual report of the IMF on exchange arrangements and exchange restrictions (IMF, 2022), 80 countries have an exchange rate anchor, while 25 have a monetary aggregate target. An inflation targeting framework functions in 45 states, while 43 countries have other systems. The latter includes countries that have no explicitly stated nominal anchor, but rather monitor various indicators in conducting monetary policy and inflation is usually one of these indicators. The central banks of advanced economies either target inflation or keep an eye on some other variables (typically economic growth or unemployment) beside inflation.

3.3. Channels of the monetary transmission mechanism

3.3.1. Interest rate channel

Conventionally, four different channels of monetary transmission can be identified: interest rates, asset prices, exchange rates and credit channels. According to Keynesian monetary theory, the interest rate is the traditional channel through which monetary policy affects the real economy (Mishkin, 1996).

In many countries the interest rate channel is probably the most important one in the monetary transmission mechanism. The change of the policy rate is transmitted to the interbank rates which influences corporate and residential interest rates, provided that the interest rate channel works effectively.

As a result of a monetary expansion (tightening), real interest rates fall (rise), and thus, the cost of capital decreases (increases), leading to higher (lower) investment and consequently a rise (drop) in output. However, a change in interest rates influences not only business investments, but consumer decisions on housing and expenditure on durable goods as well (Mishkin, 1996). A drop (rise) in interest rates discourages (encourages) saving, since the yields become lower (higher) and encourages (discourages) investment and consumption because credit becomes cheaper (more expensive). Nevertheless, the effects of interest rates depend on the interest rate sensitivity of investment and consumption. Furthermore, the corporate and the residential sectors are heterogeneous. Business investment may be influenced by the form of financing, while consumption is probably determined by financial wealth and households' marginal propensity to consume (MNB, 2012; Békési et al., 2016).

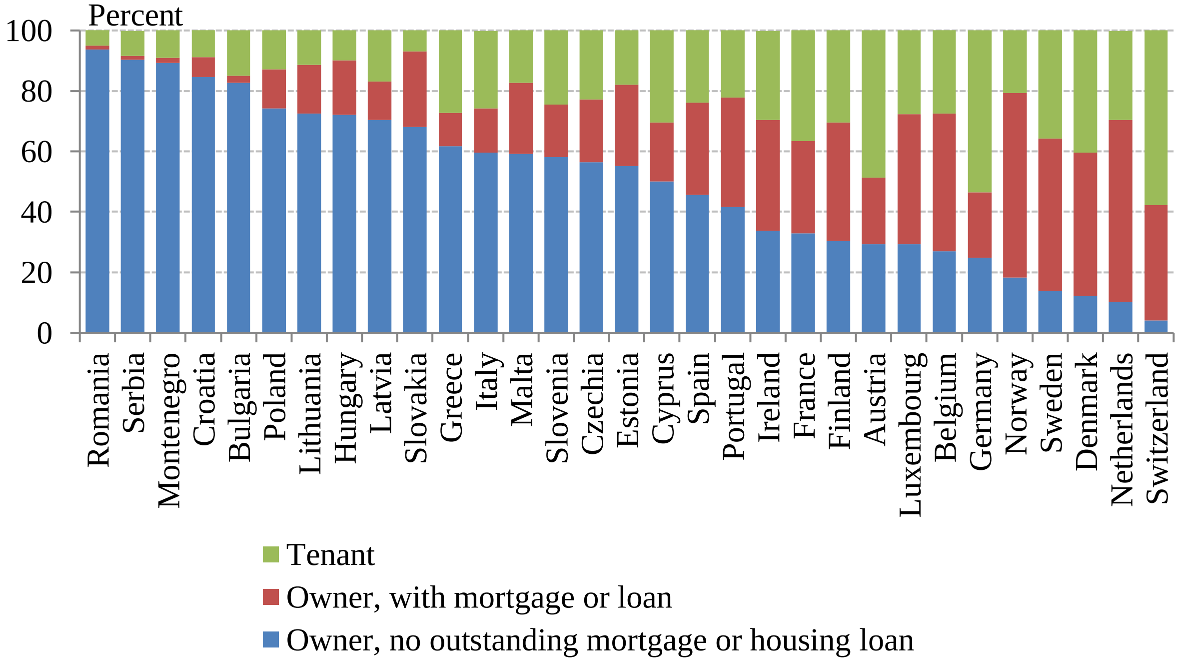
The characteristics of the financial system determine the functioning of the interest rate channel to a great extent. Sellon (2002) examines the effects changes in the US financial system have had on the monetary transmission mechanism. From the 1970s deregulation of financial markets, growth of capital markets, development of new financial instruments and the increased transparency in the field of monetary policy altered the interest rate channel of the transmission mechanism in the United States. Sellon (2002) presents three implications for the interest rate channel: bank lending and mortgage rates became more responsive to monetary policy changes, they respond faster than previously, and the increased use of variable-rate loans and lower costs of mortgage refinancing might broadened the scope of the interest rate channel. These results suggest the strengthening of the interest rate channel. However, the paper also emphasizes the role of market expectations regarding future monetary policy decisions.

Angeloni et al. (2003) study the monetary transmission mechanism in the Euro Area. The authors find that in some member states, the interest rate is the main channel of monetary transmission, and it plays an important role in other countries as well. In those member states where the interest rate is not the major channel that transmits monetary effects, there are evidence that supports the presence of a bank lending channel (or other financial channel).

Using survey data, Cloyne et al. (2018) examine the impact of interest rates on household consumption in the United Kingdom and the United States. An interest rate cut by the central bank increases the income of households, but there are differences in the response of households depending on their tenure status. Outright home owners do not adjust their consumption, mortgage holders increase their spending, while renters also react by raising their expenditures but not as much as mortgage holders. Mortgage borrowers tend to hold a small amount of liquid assets and have a high marginal propensity to consume. As mortgage holders are the largest housing tenure group in the UK and the US, their behavior drives the response of aggregate consumption and has implications for the transmission of monetary policy.

However, in many European countries the largest tenure group is owner-occupiers, who have no mortgage or loan on their property (*Figure 8*). Based on Eurostat data from 31 European countries, owner-occupiers are the largest tenure group in 19 countries. In 2022, at least half of the population lived in their own home in 17 countries. The distribution of the population by tenure status is therefore different from that in the UK and the US, which may provide different insights for policy-makers.

Figure 8: Distribution of the population by tenure status in European countries (2022)



Source: Constructed by the author based on Eurostat data

Holm et al. (2021) also examine household heterogeneity related to interest rate transmission using Norwegian data. A New Keynesian heterogeneous agent (HANK) model framework is used to capture the direct and indirect effects of monetary policy shocks on households. The authors rank households according to their liquid asset positions and estimate impulse responses based on the distribution. After a monetary tightening, disposable income starts to fall and households with low liquidity react by reducing consumption. Meanwhile, households around the median initially save less or borrow more. These results confirm the existence of borrowing constraints faced by households with low liquidity, which prevent consumption smoothing in this segment. The authors also study how the net financial income of households is affected by a monetary policy shock. They find that rising interest rates lead to an increase in the interest income of net creditors, which has a positive effect on consumption in this segment. Meanwhile, the increase in the interest expense of net borrowers results in a reduction of spending at that end of the liquid asset distribution.

The paper by Holm et al. (2021) provides further important implications for monetary policy. In countries where the distribution of assets and debt is more unequal than in Norway, the heterogeneity of household consumption is even greater. The prevalence of variable-rate mortgages and deposit elasticity do matter. A higher share of fixed-rate mortgages and lower elasticity suggest a more subdued transmission.

3.3.2. Asset price channel

In contrast with Keynes, the monetarists emphasized the importance of other asset prices beside the interest rate and criticized Keynesian monetary theory for focusing on only the interest rate. According to the monetarist theory, the transmission mechanism operates through asset prices and real wealth transmits the effects of monetary policy into the real economy. Mishkin (1996) demonstrates how the asset price channel works through the q theory of Tobin (1969). According to the theory, monetary policy influences the valuation of equities. Tobin defines q as the market value of companies divided by the replacement cost of capital. A high q indicates that the market value of firms is relatively high compared to the replacement cost of capital, so capital goods are relatively cheap. This indicates that companies issue equities and raise investment spending. However, if q is low, the relative cost of capital is high compared to the market value of firms, which leads to low investment spending.

If the money supply rises (falls), people will have more (less) money than they want to hold, so they increase (decrease) their spending, which results a higher (lower) demand for equities (Mishkin, 1996). As demand raises (drops), so do prices, which leads to an increase (decrease) in the market value of firms. This process results in a higher (lower) *q* which means more (less) investment.

Through the asset price channel, monetary policy can influence consumption as well. According to the life cycle hypothesis of Modigliani (1971), consumption is determined by wealth. Agents try to smooth their consumption spending during their lifetime; in the early phase they borrow, in the active years they repay their loans and save, finally they spend their savings after retirement. Although the life cycle hypothesis was later modified and amended, from the perspective of monetary transmission, the major point is that monetary policy can alter the value of assets that agents hold. It follows that monetary policy can influence consumption, since it is determined mainly by wealth.

Consumption is fairly permanent, while investment can show a high volatility, which is displayed in the GDP growth. Forecasting investment received the attention of researchers, and several studies examined the q theory of Tobin. As Davis (2011) discusses, macro equations, using *q* alone to explain investment, do not support the theory. Altissimo et al. (2005) suggest that the reason behind empirical results is that the assumptions of the theory (stock markets are efficient, so prices should reflect the value of companies and should contain all available information) may not hold. Valuations of companies by managers and the market may diverge for various reasons: the information base may not be the same or the market may not value assets based on solely fundamentals. Some papers (Blanchard et al., 1993; Bond & Cummins, 2001) divided the share price to a fundamental and a residual (speculative) value but the supposed positive relationship between share prices and investment is still not supported by the results.

On the other hand, studies (Ashworth & Davis, 2001; Assarsson et al., 2004; Davis & Stone, 2004) that involved other variables in the analysis beside *q* found some evidence about the effects of share prices on investment. Nevertheless, this indicates that stock markets are not highly efficient, there are measurement problems regarding *q*, or *q* is not a good determinant of investment spending (Altissimo et al., 2005; Davis, 2011).

According to the q theory of Tobin, there is a relationship between *q* and residential investment. The supply of houses should increase when house prices are higher than construction costs (Altissimo et al. 2005). Empirical studies (Barot & Yang, 2002; Jud & Winkler, 2003; Berg & Berger, 2006) confirm the theory in case of housing investment.

Paul (2020) examines the impact of monetary policy shocks on asset prices and the real economy in the United States. The author uses monetary policy surprises as a proxy for structural monetary policy shocks and integrates the surprises as an exogenous variable in a vector autoregressive model. According to the results, stock and house prices show significant time variation in response to unanticipated changes in monetary policy. The response of stock prices shows no systematic pattern, while the response of house prices is strongly correlated with the level of house prices over most of the sample. House prices are less responsive when they are high and more responsive when they are low. Another finding of the paper is that the response of stock and house prices before the 2008 financial crisis was particularly low. Therefore, the attempts of the Federal Reserve to counteract the house price boom may have been less effective.

3.3.3. Exchange rate channel

In an open economy the exchange rate can have a significant role in influencing the development of inflation and output.

An interest rate reduction (increase) lowers (raises) the yield on assets denominated in domestic currency which makes foreign currency denominated assets more (less) attractive, so investors transfer their money towards (away from) those assets. This raises (lowers) the supply of the domestic currency, which leads to a decline (increase) in its value, so the domestic currency depreciates (appreciates). As a consequence of the depreciation (appreciation) domestic goods become relatively cheaper (costlier) compared to foreign goods, which leads to a fall (rise) in imports. At the same time, domestic products become more (less) attractive to foreign consumers, which raises (reduces) exports. Therefore, net exports increase (decrease), which ceteris paribus results a higher (lower) aggregate demand (Mishkin, 1996).

However, the above mentioned effects depend on several factors. An important one is elasticity: the interest rate elasticity determines the transfer of financial investments whereas price elasticity influences the above-mentioned substitution in the goods market. Domestic products may not be perfect substitutes for foreign ones, so consumers may prefer the foreign goods, even if they are more expensive. It is possible that import products cannot be replaced immediately.

Coenen and Wieland (2003) study the role of the exchange rate in a near-zero interest rate environment, in the case of Japan. When nominal interest rates cannot fall further, the emergence of a liquidity trap can be avoided by a devaluation of the domestic currency. However, these kinds of policies have non-negligible beggar-thy-neighbor effects, which question their applicability. Furthermore, the applied model has major limitations. It does not take into consideration the financial sector, which plays a crucial role in the transmission mechanism of monetary policy, and it does not include the major Asian trading partners of Japan, so the spillover effects of a yen devaluation are limited.

The above-mentioned mechanism describes the functioning of the trade channel. Although depreciation of the domestic currency can stimulate the economic activity, the financial channel may have an adverse effect (Kearns & Patel, 2016). If banks and non-banks have liabilities denominated in foreign currency, a depreciation has valuation effects; it weakens domestic balance sheets, which can lead to the tightening of domestic financial conditions. Using trade-weighted and debt-weighted exchange rates, Kearns and Patel (2016) come to the conclusion that the financial channel partly offsets the trade channel for emerging markets, while its effects are weaker in advanced economies. In Switzerland and Denmark, an important motivation behind the adoption of the negative interest rate policy was to avoid the appreciation of the domestic currency (SNB, 2014; Danmarks Nationalbank, 2015). This indicates an essential role of the exchange rate in monetary transmission. Since the NIRP was introduced in advanced economies where the domestic currency often functions as a safe haven currency (Euro, Swiss franc, Japanese yen), I do not expect the financial channel to offset the effects of the trade channel.

Jasová et al. (2016) examine how the exchange rate pass-through to CPI inflation has altered in advanced economies and in emerging markets after the global financial crisis. The results show that the exchange rate channel has weakened in emerging markets after the crisis. In advanced economies, the exchange rate pass-through to inflation already stabilized at a lower level than in emerging markets, before the crisis. The weakening effect of the exchange rate on inflation is supported by other papers (McCarthy, 2000; Takhtamanova, 2010; Özyurt, 2016). Takhtamanova (2010) studies how the exchange rate pass-through changed in OECD countries. The author comes to the conclusion that the main reason behind the declining pass-through from the 1990s is low inflation which prompts firms to update their prices less frequently. According to the paper, the reduction in exchange rate pass-through cannot be permanent. If inflation increases in the future, the exchange rate channel will strengthen.

3.3.4. Credit channel

Banks play a crucial role in the financial sector since they can solve information asymmetry effectively in credit markets. If bank loans and other sources of funds available for corporations are not perfect substitutes of each other, a monetary expansion (tightening) raises (reduces) bank reserves, which leads to a rise (drop) in the quantity of available bank loans that can support (discourage) investment and consumption (Mishkin, 1996).

The balance sheet channel describes the impact of monetary policy on borrowers. Banks usually provide collaterized loans. A monetary expansion (tightening) raises (lowers) the value of collaterals through the asset price channel which means that borrowers can get a larger (smaller) amount of loans that may stimulate (discourage) investment and consumption (MNB, 2012).

Bernanke and Gertler (1995) support the existence of the credit channel by pointing out that the traditional cost-of-capital effect does not explain sufficiently the magnitude, the timing and the composition of the reaction of macroeconomic variables to monetary shocks.

Tsatsaronis (1995) compares the Anglo-Saxon and the continental models and, based on their characteristics, supposes that the credit channel is stronger in Germany and in Japan, and it is weaker in the United Kingdom and in the United States. In a continental model, non-financial corporations depend more on bank loans and banks actively take part in corporate governance, which factors influence the costs of financial relations. A strong banking sector makes bank loans more attractive and they are not easily substitutable by other external sources of financing. Consequently, the credit channel may be stronger than in the Anglo-Saxon model, in which the role of capital markets is more influential. However, the results are mixed. There is some evidence of a credit channel in Japan and in the UK, but in Germany and in the US bank loans do not constitute an independent channel of monetary transmission. So the hypothesis based on the differences of the Anglo-Saxon and the continental models cannot be confirmed. Nevertheless, the author emphasizes that a clear conclusion cannot be made.

3.3.5. Expectation channel

The role of expectations is extremely important because they influence the functioning of the above-mentioned channels, and they also constitute a separate channel. Formerly, information asymmetry characterized the field of monetary policy; however, nowadays, transparency is a key feature of central bank decision-making and communication. The monetary authority can affect mainly short-term interest rates, but it can successfully influence expectations, if it operates in a transparent way and provides forward guidance to orient the markets (Eijffinger & Masciandro, 2018; Csortos et al., 2014).

Woodford (2005) studies the necessity and the effectiveness of forward guidance paying a special attention on inflation targeting (IT) monetary regimes. The paper comes to the conclusion that greater transparency increased the predictability of monetary policy, in ways that might have supported the ability of the central bank to achieve its objectives.

3.3.6. Other channels

With the evolution of research in the field of monetary transmission, several new channels have been identified. Through the cost channel, a central bank can influence the cost of production factors, if short-term production capacities are financed by short-term liabilities, so it is a supply side channel (Balogh et al., 2017).

Barth & Ramey (2000) study the existence of a cost channel of monetary transmission in the United States with vector autoregression analysis. They find that a monetary tightening is followed by falling output and rising price-wage ratios in more industries. These results are consistent with a functioning cost channel.

Borio & Zhu (2012) recognized that the behavior of economic agents is determined by their willingness to take and accept risks. A change in the policy rate influences risk perception or risk tolerance, and through that the risk of portfolios, the pricing of assets and lending.

Angeloni et al. (2015) and Andries et al. (2015) examine the relevance of the risk-taking channel of monetary policy regarding the global financial crisis. Angeloni et al. (2015) present a VAR model that confirms the existence of the risk-taking channel. They find that a monetary expansion increases bank leverage and risk, and higher bank risk leads to greater asset price volatility and the reduction of equilibrium output. Andries et al. (2015) study a sample of commercial banks in the Euro Area and identifies a negative relationship between interest rates and bank risk-taking, which supports the existence of a risk-taking channel of monetary transmission.

Wang et al. (2022) study the effects of bank market power on the transmission of monetary policy through banks to borrowers. Using data on US banks, the authors build a dynamic banking model in which imperfectly competitive banks face capital and reserve requirements and optimally choose the extent to which they pass on their costs to clients. The results show that the channels related to bank market power and capital requirements are important in the transmission of monetary policy. Another finding of the paper is the existence of a reversal effect. When the federal funds rate is low, cutting it further can actually reduce bank lending, as lower profits in the deposit market have a negative impact on bank capital. Finally, the outcomes also show that the interaction of bank market power with regulatory constraints explains most of the decline in the effectiveness of monetary transmission over time.

With regard to unconventional monetary policy measures, the literature emphasizes the role of the signaling and the portfolio-balance channels. The signaling channel is activated by the central bank's communications informing the public of its intentions regarding the future course of short-term interest rates or the implementation of other measures. The portfolio-balance channel works through central bank operations such as outright purchases of securities, asset swaps and liquidity injections, which alter the size and composition of the balance sheets of both the central bank and the private sector. Through the portfolio-balance channel the central bank aims to have an impact on prices in some specific dysfunctional segments of the financial market or to influence yields more broadly (Cecioni et al. 2019).

Melosi (2017) develops a DSGE model in which the central bank's view of macroeconomic processes is signaled through the policy rate to incompletely informed price setters. Information about inflation and the output gap is conveyed to price-setters by changes in the policy rate. The paper finds evidence of this signaling channel of monetary transmission using US data. The signaling channel turns out to enhance the effectiveness of monetary policy stabilization in the face of demand shocks. However, another important finding of the paper is that the Federal Reserve has limited ability to counteract the inflationary effects of technology shocks, as firms do not meaningfully change their expectations about aggregate technology shocks after observing a tightening of monetary policy.

The functioning of the portfolio-balance channel has been the subject of debate in the literature. Gern et al. (2015) discuss the effects of quantitative easing (QE) programs and conclude that it is difficult to isolate the impacts of asset purchase programs, and that their stimulating effects are not as strong. In addition, the authors also identify a number of risks and unintended consequences that could materialize in the medium or long term. For example, excessive risk-taking, which may fuel the emergence of asset price bubbles and increase systemic risks in the financial sector. Furthermore, ultra-loose monetary policy can be a source of capital misallocation and a blockage of necessary adjustment processes and structural reforms. Meanwhile, Priftis & Vogel (2016) find evidence of the stimulating effects of QE in the Euro Area through the portfolio-balance channel. According to the results, GDP increases by 0.3 per cent and prices by 0.5 per cent by 2016. Joyce et al. (2017) also find some portfolio reallocation in the UK. The authors analyze the investment behavior of insurance companies and pension funds. They conclude that QE led institutional investors to shift their portfolios away from government bonds and towards corporate bonds, but not towards equities.

3.4. Literature on negative interest rates

Although the transmission mechanism of monetary policy is a frequently discussed topic in the literature, the negative interest rate policy has created an unprecedented situation, by eliminating the zero lower bound on nominal interest rates. Earlier, several economists touched upon the concept of negative interest rates theoretically. However, detailed explanations how negative nominal interest rates influence the financial sector and the development of macroeconomic variables such as inflation or output only became possible after the adoption of the NIRP by major central banks. Since then, the topic – for understandable reasons – was in the limelight of research. In this section, I overview the most important theoretical concepts associated with negative interest rates and the most relevant empirical literature in the topic.

3.4.1. The role of cash in relation to negative interest rates

Formerly, it seemed obvious that nominal interest rates cannot fall below zero, since the existence of cash places a lower bound of zero on nominal interest rates (Hicks, 1937; Marques et al., 2021). Krugman et al. (1998) also rule out the presence of negative nominal interest rates based on the substitutability with cash. Nevertheless, holding large amounts of cash has also costs (storage, insurance), therefore the nominal return on cash can also be negative (Marques et al., 2021).

The idea of negative nominal interest rates can be traced back to the late 19th century. Silvio Gesell was the first proponent of negative interest rates. The so-called Gesell tax is basically a stamp tax on money that functions as a negative interest rate (Gesell, 1891; Ilgmann & Menner, 2011). The reason this tax might be imposed is to avoid the hoarding of money. Money would have an ‘expiration date’; it would need to be stamped in order to remain valid, and these stamps would have a cost (Gesell, 1958). The proposal of Gesell was taken up by

Fisher (1933) and Keynes (1936). During the Great Depression in the United States, some municipalities experimented with a time based script, however, they did not serve the goals of Gesell or Fisher (Gatch, 2006; Warner, 2010; Ilgmann & Menner, 2011). The concept of taxing money in some form recurred several times (Goodfriend, 2000; Mankiw, 2009; Seltmann, 2010), especially after the 2008 financial crisis. Assenmacher & Krogstrup (2018) studies the practical feasibility of decoupling cash from electronic money to achieve a negative yield on cash, which would make the removal of the lower bound constraint on monetary policy possible. This way to eliminate the lower bound is proposed by Buiter (2007) and Kimball (2015). Assenmacher & Krogstrup (2018) suggest that the construction of such a system is technically feasible and it would also be fully reversible. This is important because it means that an exit is possible after the normalization of the macroeconomic environment. Nevertheless, communicational, financial and legal challenges are associated with a dual local currency system and the paper raises several issues and unanswered questions that should be addressed if a possible introduction of this system is seriously considered.

3.4.2. Effective lower bound, reversal interest rate and the natural rate of interest

As Brunnermeier & Koby (2017) write, in most New Keynesian models, the economy enters a liquidity trap, when the policy rate approaches zero. However, the adoption of negative interest rate policy in some countries basically eliminated the zero lower bound on policy interest rates. Although inflation and economic growth continued to be rather modest in NIRP-adopter countries, interest rates remained only mildly negative for several years. No central bank cut interest rates into deeply negative territory. As a result of these developments, the concept of the existence of an effective lower bound (ELB) became an important area of monetary policy research. De Fiore & Tristani (2019) define the ELB as a rate below which it becomes profitable for financial institutions to exchange central bank reserves for cash. Brunnermeier & Koby (2017, 2018) argue that the effective lower bound is given by the reversal interest rate, the rate at which accommodative monetary policy becomes contractionary for lending. If the central bank cuts the policy rate below the reversal interest rate, lending falls and the original goal of monetary policy, to stimulate economic growth cannot be reached by further interest rate cuts. The reversal interest rate is determined by the asset holdings of banks with fixed interest payments, the degree of interest rate pass-through to lending and deposit rates, the strictness of capital constraints bank face and the initial capitalization of banks. The authors also claim that interest rate reductions can have heterogeneous effects across regions, the reversal rate may differ, and so monetary policy can be expansionary in one region and contractionary in another one. According to the authors, quantitative easing increases the reversal rate and QE should only employed after the exhaustion of interest rate policy.

Repullo (2020) reviews the model of the reversal interest rate outlined by Brunnermeier & Koby (2018). The idea behind the concept of the reversal rate is that excessively low policy rates reduce the capital of banks which results in the contraction of lending. On the other hand, Repullo (2020) states that providing that the capital constraint is binding, low policy rates can only lead to a reduction in bank lending, if the bank is a net investor in debt securities, a condition that is usually only satisfied by high deposit banks (those with more deposits than loans). Meanwhile, if the capital constraint is not binding, lower policy rates always lead to higher bank lending. Consequently, there is no single reversal interest rate. Whenever the reversal rate exists, it is determined by bank-specific characteristics. The findings of Repullo (2020) are consistent with the empirical results of Heider et al. (2019)[2], who come to the conclusion that negative interest rates lead to less lending by banks with a higher reliance on deposit funding. The outcome of Repullo's paper (2020) is also in line with the findings of Eggertsson et al. (2019), whose research showed that when the policy rate had become negative, those Swedish banks that depend more heavily on deposit financing, experienced lower credit growth.

In relation to negative interest rates and the effective lower bound there is a further concept that needs to be discussed briefly, the natural or neutral rate of interest. The notion of the natural interest rate can be traced back to a Swedish economist, Knut Wicksell (1898) and can be defined in several ways. Holston et al. (2017, p. 59) mention the following interpretation: "the real short-term interest rate consistent with output equaling its natural rate and constant inflation". Summers (2016) describes the natural rate as the level of the real interest rate which balances saving and investment at full employment. Another definition links the natural rate to the marginal productivity of capital. Amato (2005) writes that Wicksell also used more interpretation of the natural interest rate. He did not explicitly link them together but it can be inferred from his works that he thought the definitions are mutually consistent.

The natural rate of interest has an important role in macroeconomic and monetary theory, since it can act as a benchmark for measuring the stance of monetary policy. Monetary policy can be considered expansionary (contractionary) if the short-term real interest rate is below

---

[2] See below in more detail in the empirical literature on negative interest rates section.

(above) the natural rate. The concept of the natural rate appears in interest rate rules for monetary policy as well. According to the Taylor (1993) rule the real interest rate exceeds its natural level when inflation is above target. The natural interest rate is a latent variable, it cannot be directly observed, it has to be inferred from data, which makes its measurement challenging (Holston et al. 2017). Applying the Laubach-Williams (2003) methodology Holston et al. (2017) estimate the natural interest rate for Canada, the Euro Area, the United Kingdom and the United States. Using data on real GDP, inflation and the short-term interest rate highly persistent components of the natural rate of output, its trend growth rate and the natural rate of interest are extracted with a Kalman filter.

In the literature, several methods are adopted to obtain the natural rate. Hamilton et al. (2016) use a vector error correction model (VECM) to capture the behavior of the U.S. real interest rates. Kiley (2015) applies Bayesian methods and addresses the econometric and empirical challenges of the estimation, while Fiorentini et al. (2018) build a panel error correction model. The authors of the last paper also review the Laubach-Williams (2003) methodology and argue that the estimation of the natural interest rate becomes less precise if the IS curve is flat (the output gap is insensitive to the real interest rate gap) or if the Phillips curve is flat (inflation is insensitive to the output gap). The paper suggests alternative approaches for the estimation of the natural interest rate, an augmented version of the model and a panel error correction model, using a set of indicators as potential drivers of the natural interest rate.

Several papers (Hamilton et al., 2016; Holston et al., 2017; Juselius et al., 2016; Kiley, 2015; Lubik & Matthes, 2015; Williams, 2015) document the fall of the natural interest rates in the past decades. In relation to the negative interest rate policy, the importance of the natural rate is given by its benchmark role in monetary policy. Before the coronavirus pandemic the subdued economic performance in several countries and the reluctance of central banks to cut interest rates into deeply negative territory raised the hypothesis of secular stagnation again. The expression was put forward first by Alvin Hansen (1939) in the 1930s and revived by Lawrence Summers at an IMF conference in 2013 (Backhouse & Boianovsky, 2016)[3]. The state of secular stagnation occurs when the natural interest rate is so low, that it cannot be reached through conventional monetary policies. The desired level of savings exceeds the desired level of investments which leads to a decline in demand and through that lower economic growth (Summers, 2016). As Holston et al. (2017) write monetary policy can be considered expansionary if the short-term real interest rate is below the natural rate. The

---

[3] For a detailed discussion about secular stagnation see Backhouse & Boianovsky, 2016.

authors estimate the natural interest rate between -1 and 2 percent in Canada, the Euro Area, the United Kingdom and the United States. The estimations of Fiorentini et al. (2018) are even lower for these countries, which may indicate the necessity of negative interest rates in order to provide further monetary stimulus to the economy.

Lilley & Rogoff (2019) argue for the implementation of unconstrained negative interest rate policy as a long-term solution to the effective lower bound on policy interest rates. The authors highlight that they distinguish between the very limited NIRP that was adopted in Europe and Japan, and the unconstrained negative interest rate policy they consider. The alternative possibilities (quantitative easing, fiscal QE, helicopter money, forward guidance and raising inflation targets) and their limitations are overviewed. The authors come to the conclusion that if small depositors are excluded, the pass-through of negative interest rates to large and wholesale bank depositors should be straightforward. Providing that, the large-scale hoarding of physical currency by financial firms, insurance companies and pension funds can be prevented with administrative measures. The issue of bank profitability can also be solved if the transmission of negative rates to large depositors is possible. The implementation of an effective unconstrained negative interest rate policy requires several legal, regulatory and tax changes and it cannot be adopted by the central bank alone. The obstacles vary across countries. The authors also state that NIRP adopters have not tackled the main challenge of the policy, the hoarding of paper currency. However, the hoarding of large amounts of cash is already quite expensive for financial institutions, insurance companies and pension funds, which makes mildly negative interest rates possible. Lilley and Rogoff (2019) acknowledge the drawbacks (being untried and the possibility of unintended consequences) of the unconstrained negative interest rate policy they propose but they believe the alternative options for restoring the effectiveness of monetary policy are not particularly attractive or sustainable.

3.4.3. Empirical literature on negative interest rates

Most of the empirical literature studying the transmission of negative interest rates concentrates on the Euro Area, Switzerland or some other countries conducting negative interest rate policy. The major concern – beside the transmission of negative rates – is usually profitability of commercial banks and risks to the financial sector. The characteristics of the financial system determine the effectiveness of monetary policy to a great extent, and the focus on risk taking is also understandable, especially after the global financial crisis.

Arteta et al. (2016) briefly demonstrate how the different transmission channels should operate under negative interest rates. Reducing the policy interest rate below zero should lead to lower market interest rates, similar to rate cuts in positive interest rate environment. However, commercial banks may be reluctant to impose negative interest rates on their clients; therefore the NIRP may weaken the pass-through of policy rate changes to deposit and lending interest rates. Negative rates also influence the credit channel. They actually function as tax on liquidity hoarding, which should encourage banks to increase lending. However, adverse effects can emerge, if banks raise their lending rates in order to cover the losses associated with negative interest rates. Regarding the portfolio or asset price channel, lower interest rates should increase asset prices, which lead to higher investment. Nevertheless, NIRP may distort the valuation of assets and result in the emergence of asset price bubbles. Finally, an interest rate cut should induce the depreciation of the domestic currency which can promote net exports. However, if several countries are conducting NIRP, that may lead to competitive devaluations.

Beside the transmission channels Arteta et al. (2016) also examine how the NIRP affects key financial variables and financial stability. The results vary across countries but overall it seems that negative interest rates provided additional monetary stimulus at the time of the analysis. Money market rates, short-term government bond yields and lending rates usually fell. Depreciation of the domestic currency was observed in some cases. On the other hand, inflation expectations continued to decline in most of the countries. Regarding financial stability, the paper touches upon the erosion of bank profitability and the possibility of excessive risk taking. Nevertheless, the authors also mention that most central banks introduced complementary policy measures to mitigate the potential negative effects of NIRP.

The empirical experiences – sluggish or fragile economic growth in the countries with a negative policy rate – raise the question of whether at zero or negative nominal interest rates does the monetary transmission mechanism truly work as it does at positive interest rates. Eggertsson et al. (2017) study the transmission of interest rates in the Euro Area, Denmark, Japan, Sweden and Switzerland with a simple New Keynesian DSGE model. The paper comes to the conclusion that commercial banks do not follow the interest rate reductions of the central bank once their deposit rates approach zero, and lending rates reach approximately the two percent level. This implies that the zero lower bound becomes effective for commercial banks, and the pass-through to commercial bank interest rates collapses.

Consequently, the central bank cannot provide further stimulus to the economy through the interest rate channel with conventional interest rate policy.

A comprehensive analysis about the impact of negative interest rates on the transmission mechanism and bank profitability was conducted by Jobst & Lin (2016). The authors find that NIRP had positive effects on the economy; it contributed to the reduction of bank funding costs and to the boost in asset prices. Moreover, it also strengthened the forward guidance of the European Central Bank. The reduction of lending rates and the easing of lending standards resulted in a modest credit expansion which supported the economic recovery. According to the paper, negative effects of the NIRP on bank profitability have not yet materialized at the time of the analysis. However, the authors mention that the outlook for bank profitability worsened, especially in Euro Area countries with a high share of variable rate loans (and a high dependence on deposit funding). Although most banks were able to mitigate the negative effects with greater lending volumes, higher asset prices and lower funding costs, further substantial reductions of the deposit facility rate could weaken the monetary transmission if lending rates do not adjust and/or customers withdraw their money from the banks.

Claeys (2021) analyzes the effects of the negative interest rate policy in the Euro Area. The author examines the impact of rate cuts in negative territory with error correction models and comes to the conclusion that they are not different from rate cuts in positive territory. A further finding of the paper is that interest rates on the assets of banks are more sensitive to the changes in the policy rate than the rates on the liabilities of banks. However, this effect does not appear to be amplified by moderately negative rates. Claeys also touches upon the risks associated with negative interest rates. The author believes that negative side effects have not materialized, however, a careful monitoring is necessary in order to avoid the emergence of potential financial imbalances.

Thornton and Vasilakis (2019) examine the effects of negative interest rates on the exchange rate, using the difference-in-differences method. The authors come to the conclusion that in those countries where the NIRP has been adopted, the volatility of the exchange rate declined and the domestic currency depreciated compared to the control group. These results confirm the assumptions of Arteta et al. (2016) about the functioning of the exchange rate channel under negative interest rates. Similar to Arteta et al. (2016), Thornton and Vasilakis (2019) mention the risks of exchange rate depreciation.

Honda & Inoue (2017) study the effects of negative interest rates in Japan, using a simple analytical model. According to the paper, interest rates on bonds and the required rate of return from stocks were lowered and the yen depreciated. The results are in line with the predictions of the model. The authors come to the conclusion that the NIRP had expansionary effects; therefore it is a legitimate tool in alleviating the zero lower bound. However, the applied model is overly simplified, so it has serious limitations. The financial sector is exogenous; private banks play no role in the transmission mechanism. In reality, banks are crucial actors that certainly react to the reduction of their profits due to negative interest rates, and NIRP influences risk taking in the banking sector. For simplicity, the applied model ignores expectations whereas they have a crucial role, especially in financial markets. As a consequence of these simplifications, the conclusions of the paper may be questionable. The authors emphasize that their work is an early assessment. Based on the charts, the latest available data runs until the first half of 2017. The Bank of Japan adopted the NIRP in January 2016. In 2017, the performance of the Japanese economy improved, so it seemed that the NIRP was working. However, GDP growth proved to be fragile; it dropped under 1 percent on an annual basis in 2018, and has remained moderate since then.

The performance of the interest rate channel in Switzerland at negative interest rates is studied by Kutasi & Szabó (2019). In an error correction framework, the authors examine how the changes in the CHF Libor are transmitted into lending rates in the household sector. The results show that in the case of the variable rate mortgage loan, interest rate pass-through basically falls apart when the Libor becomes negative.

Fatum et al. (2019) examine the influence of macroeconomic news surprises on bond yields from 1999 to 2018 for Germany, Japan, Sweden and Switzerland. The authors focus on the possibility of time-variation in the influence of news coinciding with changes in the stance of domestic monetary policy. The results suggest that the influence of macroeconomic news surprises on bond yields for all four countries is either weaker or non-existent during the NIRP period, compared to the preceding zero interest rate policy (ZIRP) period. These findings indicate that monetary policy is more constrained during NIRP, compared to during ZIRP. The results are consistent with the assumption that a binding lower bound exists for countries conducting NIRP and this is a latent lower bound, since the exact position of it on the negative scale is unknown.

The effects of negative interest rates on banks and firms are studied by Altavilla et al. (2019). The authors find that sound banks can pass on negative rates to corporate depositors without suffering a contraction in funding. Moreover, the transmission becomes even stronger at negative interest rates. The results also show that corporate investment is stimulated by negative rates, since companies decrease their cash-holdings to avoid the costs associated with negative rates. According to the paper, the transmission mechanism works as it should and conventional monetary policy does not become ineffective at negative rates.

A comprehensive analysis of the experiences with negative interest rates was made by Marques et al. (2021). The authors review the conceptual issues associated with negative rates, such as the limits of NIRP, the expected effects and the cross-border spillovers. The role of cash, the effective lower bound and the reversal rate is discussed. According to the paper, NIRPs may influence international spillover effects. The behavior and the sensitivity of capital flows and exchange rates to interest rate differentials can be dissimilar when interest rates are negative. Cross-border bank lending may also vary. The pass-through of policy rate changes to bank rates is also studied with regression models and CUSUM tests. The results show that NIRP is not associated with a structural break in the transmission of policy rate changes to bank rates. However, the authors also draw attention to the limits of the analysis. The paper comes to the conclusion that the potential negative side effects related to NIRP have not yet materialized or have turned out to be less relevant than expected earlier. It seems that the transmission mechanism does not change significantly when interest rates become negative. Overall, bank profitability has not declined substantially. Consequently, the reversal rate has not yet been reached and banks do not appear to have engaged in excessive risk-taking. The paper also mentions some further areas for research. The impact of negative interest rates on non-bank financial intermediaries (e.g. pension funds, insurance companies) received little attention so far. The role of bank competition is also neglected by researchers. According to the authors, more attention should be paid on the corporate channel, identified by Altavilla et al. (2019), since it is still unclear what drives this channel.

Heider et al. (2019) use the difference-in-differences method to study bank lending behavior of Euro Area banks with different deposit ratios before and after the European Central Bank sets negative policy rates in 2014. Since banks are reluctant to pass on negative interest rates to depositors, the funding costs of high-deposit banks increase, reducing their net worth compared to low-deposit banks. The introduction of negative policy rates leads to more risk taking and less lending, in the case of banks with greater reliance on deposit funding. Consequently, the negative interest rate policy not only fails to be accommodative, but poses a risk to financial stability which, understandably, became a major concern of central banks after the global financial crisis.

Risk in the banking sector regarding negative interest rates is also studied by Nucera et al. (2017). The authors find that the risk impact of negative interest rates is moderate and depends on the business models of banks. Large banks with diversified income streams are perceived by the market as less risky, while more traditional banks that rely mainly on deposit funding seem more risky. The paper also concludes that a policy rate cut in negative territory has a different impact on risk responses than an earlier cut to zero.

Amzallag et al. (2019) examine the behavior of Italian mortgage lenders using a loan level dataset. Applying the difference-in-difference method the authors find that certain features of the funding profile of a bank influence mortgage rates. Banks with higher ratios of overnight deposits to total assets tend to charge higher interest rates on new fixed rate mortgages if the policy rate is negative. The pricing of adjustable rate mortgages is not affected by the negative policy rate. The analysis also points out that banks with a higher overnight deposit ratio are more likely to provide adjustable, rather than fixed rate mortgages, if the policy rate is negative.

Using a bank-level dataset comprising more than 6500 banks from 33 OECD member countries Molyneux et al. (2020) study bank lending behavior. The authors are interested in whether the adoption of the negative interest rate policy resulted in a change in bank lending. The outcomes of the analysis suggest that bank lending was weaker in those countries where the NIRP was introduced. According to the paper several bank characteristics strengthen the adverse effects of the negative interest rate policy. The negative effects of NIRP were stronger for banks that are smaller, less well capitalized, more dependent on retail deposit funding, more reliant on interest income and operate in more competitive markets.

A further aspect of negative interest rates is studied by Corneille et al. (2021). Using an online experiment the authors investigate what leads people to accept negative interest rates on their savings. The results show some tolerance of negative rates which means that people are willing to hold money in a bank instead of spending it and they accept less savings at some future time. According to the paper, the tolerance of negative rates depends on the amount of savings, the time horizon, actual savings behavior and anchoring. A higher amount of savings and a longer time horizon are associated with a lower level of tolerance. The results are consistent with a reverse magnitude effect, that the interest to be paid seems lower in absolute value for a small amount of savings. Regarding the time horizon, the outcomes suggest that people do not prefer to commit to losses for a longer time. Regular savers are more likely to accept negative interest rates, which is consistent with status quo bias, higher familiarity with savings deposits and a future-oriented mindset. The authors interpret these findings in the following way: regular savers care about the future and negative interest rates do not prevent them from saving. Anchoring also matters, the tolerance of negative rates is higher when people first face negative rates and then positive ones, than the other way around.

A categorization based on the topics of the above reviewed empirical literature is provided in *Table 1*. The importance of examining the monetary transmission mechanism at negative nominal interest rates is quite evident.

Table 1: Topics of the empirical literature regarding negative interest rates

Transmission mechanism	**Bank profitability and other issues regarding banks**	**Comprehensive analysis (transmission and banking sector)**
Claeys (2021), Eggertsson et al. (2017), Fatum et al. (2019), Honda & Inoue (2017), Kutasi & Szabó (2019), Thornton & Vasilakis (2019)	Heider et al. (2019), Molyneux et al. (2020), Nucera et al. (2017)	Altavilla et al. (2019), Amzallag et al. (2019), Arteta et al. (2016), Jobst & Lin (2016)

Source: Constructed by the author

3.5. Monetary transmission in the Euro Area

For the analysis of monetary policy in the Euro Area, it is important to touch on the main points of economic integration theories. Economic integration is established with a view to developing and promoting economic cooperation between the participating countries. Important work in the field of integration theory was done by Béla Balassa (1961). The following stages of integration can be distinguished according to the degree of cooperation between member states (Halmai, 2020):

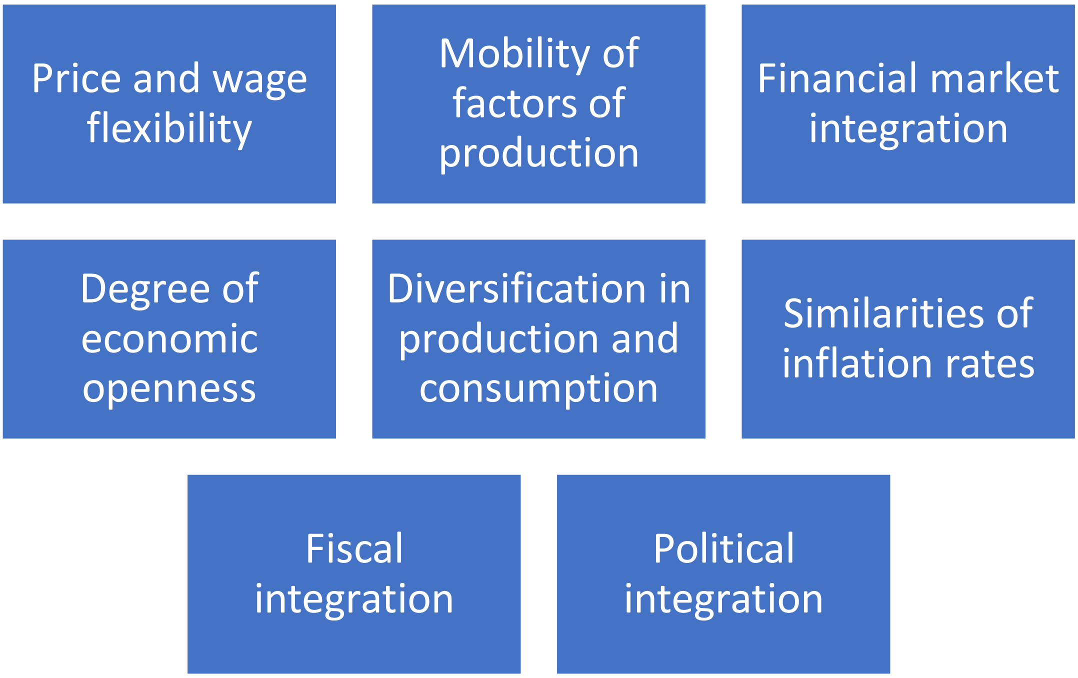
- **Preferential customs zone:** members offer each other discounts in order to facilitate access to their own markets for goods from the partner country.

- **Free trade area:** the countries in the free trade area do not apply tariffs and quantitative restrictions to each other, but have an autonomous trade policy towards countries outside the area. The preferential customs area and the free trade area are a step in the direction of integration, but neither of them can be considered as a form of integration in itself.
- **Customs union:** trade within the area is liberalized and a common trade policy is pursued with outsiders.
- **Common market:** the four freedoms (free movement of goods, services, capital and labor) have been achieved, but economic borders remain.
- **Single market:** an improved version of the common market where "non-tariff" physical (e.g. border controls), financial (e.g. tax rules) and technical (e.g. standards) barriers to trade are removed.
- **Economic union:** the integration of economic policies is achieved, with the aim of coordinating and harmonizing national economic policies. The basic element is the single currency and the monetary union it will bring about (a single central bank is created, monetary policy and exchange rate policy are conducted at the supranational level).
- **Full economic integration:** fiscal integration can also be achieved through fiscal union.
- **Political union:** legislation and government are supranationalized. A unified state administration, foreign representation, defense, justice and home affairs are created. At the same time, federal governments are established.

The Euro Area is at the stage of economic union. There are efforts to achieve full economic integration (Halmai, 2020). The advocates of a deeper European integration have blamed the crisis of the euro precisely on the lack of a full economic integration (Bergsten, 2012; Spolaore, 2013).

Regarding economic and monetary integration another crucial theory was formulated along the works of Mundell (1961), McKinnon (1963) and Kenen (1969). The optimal currency area (OCA) can be defined as an optimal geographical area for a single currency or several currencies, whose exchange rates are irrevocably pegged. The single currency or the pegged currencies fluctuate jointly against other currencies. Sovereign countries, that choose to participate in the currency area, form the borders of the OCA. Optimality is defined along several properties, presented by *Figure 9.* Sharing these characteristics diminishes the need for nominal exchange rate adjustments. Later, other criteria, such as the similarity of shocks and monetary transmission, emerged (Mongelli, 2008).

Figure 9: Properties of optimum currency areas



Source: Constructed by the author based on Mongelli (2008)

Nevertheless, the theory of optimal currency areas received a large amount of criticism. The difficulty of measurement and evaluation came forth (Robson, 1987; Tavlas, 1994). The problem of inconsistency was stated by Tavlas (1994): the properties may point in different directions. For example, based on the economic openness property, small open economies should adopt a fixed exchange rate or enter a monetary integration with their main trading partner. However, they are probably less differentiated in production in which case the diversification in production property suggests a flexible exchange rate regime. Finally and most importantly, the OCA theory was not able to provide clear answers to the crucial questions of the 1970s and 1980s, whether European countries should proceed towards a monetary union and which countries would be able to join (Tavlas, 1993; Emerson et al., 1992; Mongelli, 2008).

In the 1990s, the issue of endogenous effects of monetary integration was raised. According to the endogeneity of optimal currency areas hypothesis, monetary unification may induce processes that increase the integration of the participating countries over time, they may fulfill more OCA properties in the future (Mongelli, 2008). Based on historical data, monetary integration results in a substantial deepening of reciprocal trade (Frankel & Rose, 1998; Rose, 2000; Rose & Stanley 2005). The endogeneity arises from two channels, the degree of openness and the link between trade integration and income correlation. The first one is more accepted, after the introduction of a single currency, trade is likely to increase among the member states of a monetary union. The latter one is rather disputed, monetary integration may induce specialization and asymmetry of shocks (Mongelli, 2008).

Several sources of endogeneities of OCA were identified (Mongelli, 2008):

- Reduction of direct and indirect trading costs (e.g. removal of exchange rate risks and the cost of currency hedging)
- Enhancement of price transparency and discouragement of price discrimination
- Reduction of market segmentation and facilitation of competition
- Preclusion of competitive devaluations
- Facilitation of foreign direct investment and the building of long-term relationships
- Encouragement of political integration
- Fostering of business cycle synchronization

To summarize, in a monetary union the borders are removed, the distances are narrowed and the incentives of economic agents are changed (Mongelli, 2008). In spite of its shortcomings, the OCA became a relevant theoretical framework for analyzing European integration processes.

Based on the factors mentioned by the OCA and other financial and macroeconomic indicators, heterogeneity can be observed across the Eurozone. In an optimization-based multi-country model, Jondeau & Sahuc (2008) find that the main source of heterogeneity in the Euro Area is the asymmetry of shocks affecting the countries. So even among the core economies there is no synchronization of business cycles. Consequently, a "one-size-fits-all" monetary policy may not be suitable for all member states. This issue is the subject of a discussion by Nechio (2011) in relation to the ECB's interest rate hikes in 2011. Based on the Taylor rule, the author argues that the target rate of the central bank was too low for the core Eurozone countries and too high for the peripheral economies after 2009. The Taylor rule suggested a deeply negative interest rate in the periphery.

Another important aspect of the article by Nechio (2011) is the comparison with the US. After all, the monetary policy pursued by the Federal Reserve may not be appropriate for all states. However, the US can rely on relatively high labor mobility and fiscal policy to dampen the potentially divergent effects of monetary policy. This line of thinking leads back to the preferred level of economic integration, which is the subject of ongoing debate among policymakers.

Sapir (2016) also discusses the role of the labor market and fiscal policy in absorbing asymmetric shocks. The author argues that differences in national wage formation and bargaining systems lead to misalignments within the Euro Area. Therefore, reducing labor market heterogeneity is crucial and member states should ensure that wage developments are in line with productivity developments in order to eliminate an important source of asymmetric behavior. In addition to the labor market, the improvement of capital markets and fiscal mechanisms is also mentioned.

Using cluster and factor analysis, Coudert et al. (2020) examine cross-country heterogeneity within the Euro Area. The authors identify two distinct groups prior to the introduction of the euro. Belgium, France, Germany, Ireland and the Netherlands formed the most homogeneous group. The second group consisted of Austria, Finland, Spain and Italy. Greece and Portugal had quite different equilibrium exchange rate paths, with Greece in particular being an outlier, the most idiosyncratic country. Among others, the analysis includes economic growth, inflation, the current account balance, unemployment and the debt-to-GDP ratio. The paper concludes that dissimilarities have increased both between and within groups. The members have not structurally moved closer to one another. The hypothesis of the OCA that the members of a monetary union will automatically converge over time is rejected. The authors highlight the need for reforms.

Altavilla et al. (2020) study the pass-through of monetary policy to bank lending rates and find strong heterogeneity across Eurozone countries. The capital ratio, exposure to domestic sovereign debt, the share of non-performing loans and the stability of the funding structure explain the heterogeneity in transmission. Banks that were poorly capitalized and highly exposed to domestic sovereign debt reduced their lending rates less than other banks after a monetary expansion. The authors also find a strong response of lending rates to unconventional monetary policy measures and that these tools have reduced heterogeneity. Funding cost reliefs, dynamic portfolio rebalancing and signaling effects improved conditions. The lending margins of banks with weak balance sheet characteristics declined significantly.

Not long after the global financial crisis of 2008, the Euro Area had to deal with the sovereign debt crisis, which threatened to bring down the euro and the monetary union. I do not intend to go into detail about the crises and their consequences in this dissertation, but it is important to note that the ECB introduced a number of unconventional monetary policy instruments in response to the crises, even before the negative interest rate policy. The main measures were quantitative easing, targeted refinancing operations, forward guidance and, of course, the subject of my research, negative interest rate policy.

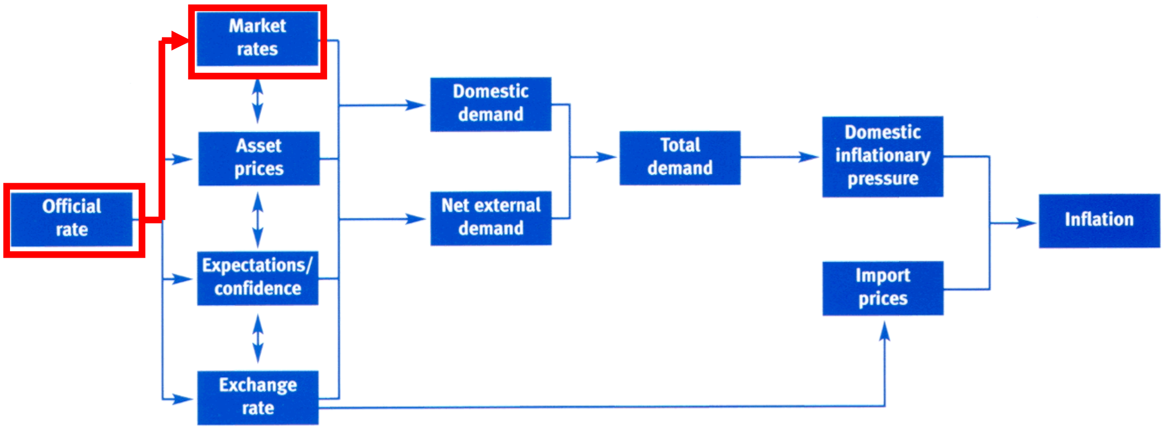
Rostagno et al. (2021) examine the effects of the ECB's unconventional monetary policy measures: negative interest rates, forward guidance and asset purchase programs. The authors point out that identifying the effects of these tools is a challenging task, so they propose a new approach by combining a dense, controlled event study with forward curve counterfactuals. The paper highlights the role of NIRP as a stand-alone instrument that can reinforce the effects of FG and QE. According to the findings, in 2019, both GDP growth and annual inflation would have been lower and unemployment would have been higher in the absence of unconventional instruments.

Zlobins (2021) studies the macroeconomic impact of the ECB's forward guidance and its interaction with asset purchase programs in a vector autoregressive framework. The author concludes that the FG led to a fall in interest rate expectations, thereby raising output and the price level. Another finding of the paper is that asset purchases increased the credibility of forward guidance. In addition, the FG reduced uncertainty in the Euro Area and lowered borrowing costs in both the corporate and household sectors.

IV. Methodology and results

Within the framework of the monetary transmission mechanism, my research focuses on the first step of the transmission via the interest rate channel (*Figure 10)*; the pass through of the changes in the official interest rates into the interest rates of commercial banks. In many countries, the interest rate channel plays a crucial role in the transmission mechanism of monetary policy. Consequently, it is important to understand how this channel functions when the interest rate falls below zero.

Figure 10: The interest rate channel of the monetary transmission mechanism



Source: Constructed by the author based on George et al. (1999)

4.1. Data

I used time series analysis to examine the transmission of interest rates across Euro Area member states[4]. I collected monthly data from the websites of the European Central Bank and estimated error correction and vector autoregressive models in Stata and EViews, which are statistical software packages.

As dependent variables, I chose two composite cost of borrowing indicators for firms and households. These indicators are accurate and comparable measures of the borrowing costs in the corporate and in the household sectors in Euro Area countries (Feraboli et al., 2015). Precisely, the indicators capture cost of borrowing for new loans to non-financial corporations and the cost of borrowing for new loans to households for house purchase. Borrowing costs

---

[4] On the 1st of January 2023 Croatia joined the Euro Area, however, the ECB already quitted the negative interest rate policy by that time, so Croatia is not part of the current analysis.

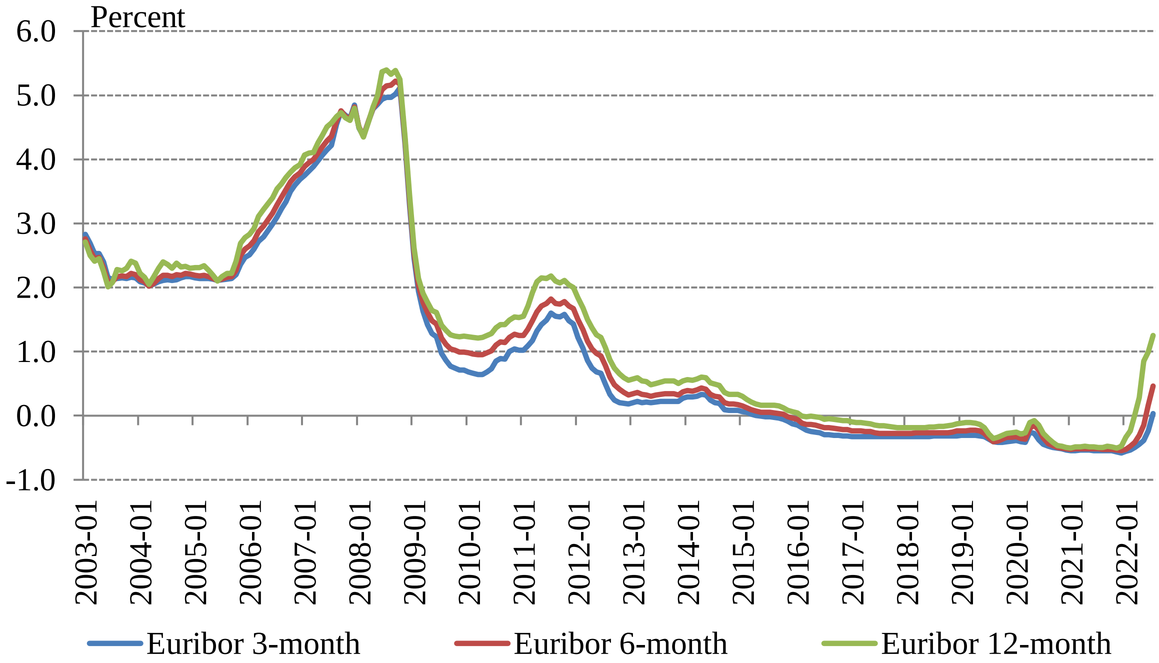
are expressed as a percentage. As explanatory variables, I used three maturities (3, 6 and 12-month) of the Euro Interbank Offered Rate (Euribor)[5]. Since key interest rates of the ECB can be unchanged for a prolonged period of time, they are not really suitable for econometric analysis, therefore I chose the Euribor, which is an important reference rate. Euribor is also measured in percentage terms. The earliest available data regarding the cost of borrowing indicators is January 2003, so this is the starting point of the analysis. The models were run until the Euribor was negative. The end points vary in line with the maturity of the Euribor. The 3-month rate was negative until June 2022, the 6-month rate until May 2022 and the 12-month rate until February 2022.

Different maturities of the Euribor moved together in the last two decades, as *Figure 11* illustrates. From the end of 2005 until the 2008 global financial crisis interest rates increased. Central banks reacted to the crisis with sharp rate cuts. Some interest rate hikes can be observed after, when inflation started to accelerate in the Euro Area due to the increase in oil prices. However, the sovereign debt crisis made the reduction of interest rates necessary. The examined maturities of the Euribor entered negative territory in 2015 and early 2016 and they remained there until 2022.

---

[5] „The Euribor rates are based on the average interest rates at which a large panel of European banks borrows funds from one another. The Euribor rates are considered to be the most important reference rates in the European money market. The interest rates do provide the basis for the price and interest rates of all kinds of financial products." https://www.euribor-rates.eu/en/

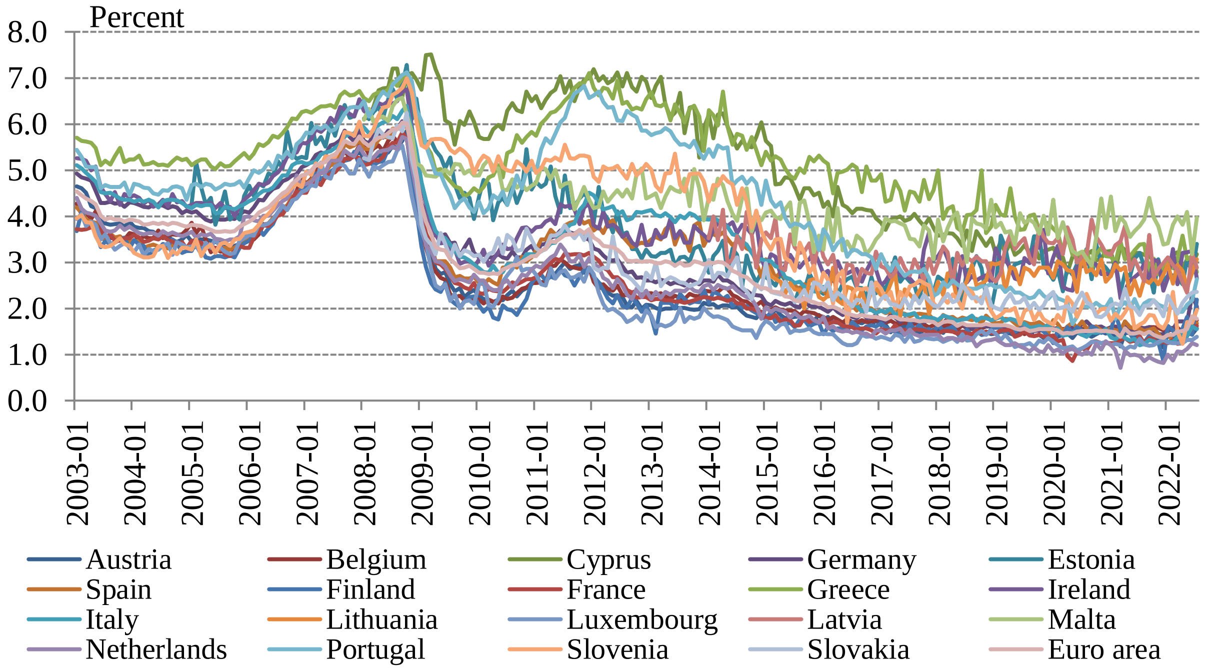
Figure 11: The evolution of the 3-, 6-, and 12-month Euribor



Source: Constructed by the author based on ECB data

Figure 12 and 13 show the dependent variables of the analysis, corporates' and households' cost of borrowing. The above written tendencies can be observed in the charts, which suppose comovement between the Euribor and the cost of borrowing indicators. There are considerable differences among Eurozone members regarding the cost of borrowing, especially in the corporate sector. The indicators did not become negative in any country in the era of negative interest rate policy. Towards the end of the negative interest rate era, the cost of borrowing indicator ranged between 1 and 4 percent in the corporate sector and fluctuated in a narrower range, between 1 and 3 percent in the household sector. The indicator showed greater volatility in the corporate sector during the entire period.

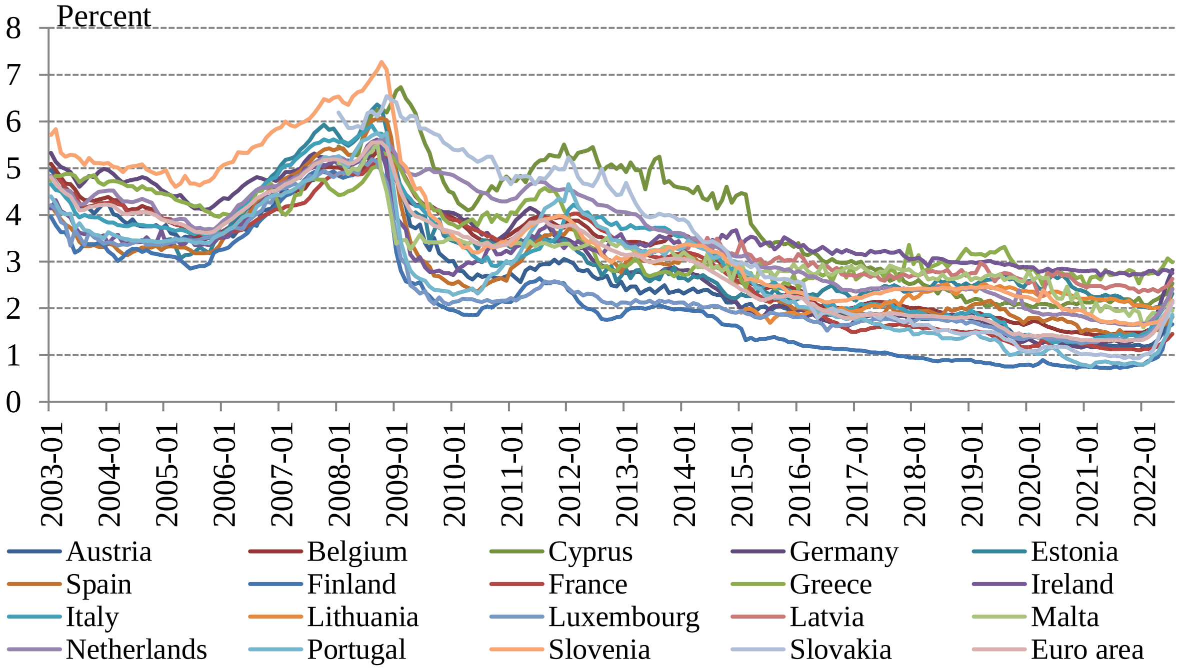
Figure 12: The evolution of corporates' cost of borrowing in Euro Area member states



Source: Constructed by the author based on ECB data

Figure 12 shows that, after the 2008 crisis, there is greater heterogeneity across countries. Between 2003 and 2006, corporate borrowing costs moved within an interval of 2 percentage points, which widened to 4 percentage points by 2010. Since then it has narrowed to 3 percentage points, which is still higher than in the pre-crisis period. Heterogeneity also increased in the household sector after the 2008 crisis, but a correction can be seen in *Figure 13* around 2015/2016. Since then, the cost of borrowing for households has moved within a range of 2 percentage points, as in the pre-crisis period.

Figure 13: The evolution of households' cost of borrowing in Euro Area member states



Source: Constructed by the author based on ECB data

Table 2 and *Table 3* provide a summary of the time series used in the error correction models. In the corporate sector, the average cost of borrowing over the whole period was lowest in Luxembourg (2.43 percent) and highest in Greece (5.14 percent). The lowest corporate borrowing cost was 0.71 percent, which occurred in the Netherlands in March 2021. The highest value (7.51 percent) was observed in Cyprus in March 2009.

Table 2: Summary statistics – Euribor and corporate sector

Variable	Observations	Mean	Median	Standard deviation	Minimum	Maximum
Euribor 3-month	234	1.05	0.33	1.59	-0.58	5.11
Euribor 6-month	233	1.17	0.48	1.59	-0.54	5.22
Euribor 12-month	230	1.33	0.97	1.60	-0.50	5.39
Corporates' cost of borrowing						
Variable	Observations	Mean	Median	Standard deviation	Minimum	Maximum
Austria	235	2.62	2.09	1.24	1.15	5.85
Belgium	235	2.69	2.29	1.19	1.44	5.75
Cyprus	175	4.99	4.83	1.52	2.76	7.51
Estonia	211	3.77	3.28	1.27	1.98	7.28
Finland	235	2.53	2.11	1.17	0.86	5.74
France	235	2.61	2.25	1.21	0.86	5.82
Germany	235	3.05	2.73	1.34	1.34	6.06
Greece	235	5.14	5.19	1.13	2.74	7.12
Ireland	235	3.79	3.57	1.08	2.22	6.75
Italy	235	3.32	3.42	1.40	1.20	6.39
Latvia	103	3.15	3.10	0.38	2.34	4.14
Lithuania	91	2.59	2.59	0.29	1.83	3.17
Luxembourg	235	2.43	1.89	1.24	1.09	5.53
Malta	175	4.26	4.15	0.75	2.93	6.57
Netherlands	235	2.64	2.44	1.33	0.71	5.72
Portugal	235	4.31	4.62	1.51	1.66	7.12
Slovakia	175	2.77	2.45	0.94	1.81	6.24
Slovenia	235	3.72	3.50	1.45	1.23	6.99
Spain	235	3.03	3.26	1.17	1.27	5.96
Euro Area	235	3.00	2.98	1.26	1.36	6.03

Source: Constructed by the author based on ECB data

In the household sector, the average cost of borrowing was lowest in Lithuania (2.16 percent) and in Finland (2.21 percent). Cyprus (3.77 percent) and Slovenia (3.64 percent) had the highest average borrowing costs for households. The lowest value (0.72 percent) was observed in Finland in June 2021, while the highest value (7.27 percent) was observed in Slovenia in October 2008.

Table 3: Summary statistics – Household sector

Households' cost of borrowing						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Austria	235	2.80	2.56	1.20	1.17	5.59
Belgium	235	3.20	3.47	1.14	1.43	5.43
Cyprus	175	3.77	3.68	1.38	2.02	6.73
Estonia	235	2.93	2.69	1.13	1.38	6.07
Finland	235	2.21	1.97	1.29	0.72	5.53
France	235	3.01	3.44	1.27	1.10	5.34
Germany	235	3.15	2.86	1.39	1.16	5.48
Greece	235	3.57	3.27	0.84	2.41	5.33
Ireland	235	3.46	3.35	0.65	2.70	5.61
Italy	235	3.18	3.41	1.25	1.25	5.91
Latvia	103	2.79	2.73	0.29	2.28	3.51
Lithuania	91	2.16	2.18	0.21	1.69	2.52
Luxembourg	235	2.54	2.14	1.09	1.25	5.19
Malta	175	3.01	2.87	0.71	1.59	5.56
Netherlands	235	3.57	3.79	1.15	1.65	5.63
Portugal	235	2.84	3.06	1.31	0.75	5.75
Slovakia	175	3.21	2.87	1.79	0.93	6.54
Slovenia	235	3.64	3.30	1.48	1.63	7.27
Spain	235	2.93	2.93	1.13	1.38	6.07
Euro Area	235	3.08	3.25	1.22	1.30	5.55

Source: Constructed by the author based on ECB data

4.2. Error correction models

I started the analysis by constructing error correction models (ECMs). The ECM can describe both long and short-term relationships between two or more variables, so it is suitable for studying how the interest rate channel of the monetary transmission mechanism functions. The long run equation of the model can be written in the following way:

$$y_t = ß_0 + ß_1 x_t + u_t \tag{5}$$

where y_t represents the dependent variable in time period *t*, which is the cost of borrowing indicator in this case, $ß_0$ is a constant, x_t represents the explanatory variable in time period *t*, which is the Euribor, $ß_1$ is its coefficient and u_t is the error term of the model. If $ß_1$ equals to 1, changes in the explanatory variable are fully transmitted into the dependent variable. However, if for example, the loan supply is not fully elastic or the banking sector is not characterized by perfect competition, the transmission is not full and $ß_1$ is smaller than 1 (Sander & Kleimeier, 2004).

I used the Engle-Granger two-step method (Engle & Granger, 1987), so I first estimated the long run equation (*Equation 5*), obtained the OLS residuals and included them in the short run equation (*Equation 6*).

The short run equation of the error correction model is similar to a model used by Claeys (2021) and is written in the following form:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta y_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta x_{t-1} + \lambda e_{t-1} + \delta I_{xt < 0} + \zeta(I_{xt < 0} * \Delta x_{t-1}) + \varepsilon_t \tag{6}$$

The equation is estimated in first differences, which is marked by Δ. The dependent (cost of borrowing indicator) and the explanatory (Euribor) variables are represented by *y* and *x*, respectively. The model takes into account the lags of the dependent and explanatory variables. The error correction term, e_{t-1} is the first lag of the OLS residuals from *Equation 5* and its coefficient, λ shows the speed of adjustment. If there is a deviation from the long-term equilibrium value, λ reveals what proportion of this deviation is corrected during one period. A dummy variable, $I_{xt < 0}$, is introduced in the equation, which takes the value of one when the Euribor is negative and it is 0 otherwise. The interaction variable, $(I_{xt < 0} * \Delta x_{t-1})$, captures the additional effect of the changes in the Euribor on the cost of borrowing indicator, when the interest rate (represented here by the Euribor) is negative. If the coefficient of the interaction variable, ζ, is not zero and statistically significant, the transmission mechanism changes when interest rates become negative. Finally, ε_t is the error term of the model.

4.2.1. Econometric tests

In order to construct an error correction model, the variables need to be cointegrated. Cointegration means that a common stochastic trend can be observed between two or more time series (Granger, 1981). I expected cointegration between the cost of borrowing indicators and one or more maturities of the Euribor. Established cointegration between the aforementioned variables points in the direction of a functioning interest rate channel. *Table 4* summarizes the results of the Johansen cointegration tests between the corporates' cost of borrowing indicators in Euro Area member states and the Euribor. The tests were performed for the entire period from the first available data to the last negative value of Euribor, i.e. June 2022, May 2022 and February 2022 for the 3-month, 6-month and 12-month Euribor, respectively. Cost of borrowing for firms is not cointegrated with any maturities of the Euribor in seven countries (Greece, Italy, Latvia, Lithuania, Malta, Slovakia and Spain) out of the nineteen member states of the Eurozone. Based on the Johansen cointegration tests, I can already suppose that the interest rate channel of the monetary transmission mechanism differ among Euro Area members, at least in the corporate sector.

Table 4: Results of the Johansen cointegration tests in the corporate sector

Cointegrated time series			Not cointegrated time series		
3-month Euribor	**6-month Euribor**	**12-month Euribor**	**3-month Euribor**	**6-month Euribor**	**12-month Euribor**
Austria, Belgium, Cyprus, Estonia, Finland France, Ireland, Luxembourg, Slovenia	Austria, Belgium, Cyprus, Germany, Estonia, Finland France, Ireland, Luxembourg, Netherlands, Slovenia Euro Area	Austria, Belgium, Cyprus, Germany, Estonia, Finland France, Ireland, Luxembourg, Netherlands, Portugal, Slovenia, Euro Area	Germany, Greece, Italy, Latvia, Lithuania, Malta, Netherlands, Portugal, Slovakia, Spain, Euro Area	Greece, Italy, Latvia, Lithuania, Malta, Portugal, Slovakia, Spain	Greece, Italy, Latvia, Lithuania, Malta, Slovakia, Spain

Note: A composite cost of borrowing indicator is calculated for the whole Euro Area as well.

Source: Estimation by the author based on ECB data

Table 5 summarizes the results of the Johansen cointegration tests between the households' cost of borrowing indicators in Euro Area member states and the Euribor. As in the case of the corporate sector, the tests were carried out for the entire period. In the household sector, cost of borrowing is not cointegrated with any maturities of the Euribor in six countries (Belgium, Ireland, Latvia, Lithuania, Portugal and Spain) and in the Euro Area. Since, the composite indicator captures the cost of borrowing for house purchases by households, I suppose that several factors can explain the lack of a common trend with the Euribor. Transmission through the interest rate channel tends to be weaker in the household sector than in the corporate sector (Claeys, 2021) and loans for households may be subsidized.

Table 5: Results of the Johansen cointegration tests in the household sector

Cointegrated time series			**Not cointegrated time series**		
3-month Euribor	**6-month Euribor**	**12-month Euribor**	**3-month Euribor**	**6-month Euribor**	**12-month Euribor**
Austria, Cyprus, Estonia, France, Greece, Italy, Luxembourg, Malta, Netherlands, Slovakia, Slovenia	Austria, Cyprus, Estonia, France, Greece, Luxembourg, Malta, Netherlands, Slovakia, Slovenia	Austria, Cyprus, Estonia, Finland, France, Germany, Greece, Malta, Netherlands, Slovakia, Slovenia	Belgium, Germany, Finland, Ireland, Latvia, Lithuania, Portugal, Spain, Euro Area	Belgium, Finland, Germany, Ireland, Italy, Latvia, Lithuania, Portugal, Spain, Euro Area	Belgium, Ireland, Italy, Latvia, Lithuania, Luxembourg, Portugal, Spain, Euro Area

Source: Estimation by the author based on ECB data

In case of time series data, the lag structure is an important factor that has to be taken into account in the analysis. The value of a variable in time period *t*, may depend on its own values in time period *t-1*, *t-2, … t-n*. Therefore, I obtained the lag-order selection statistics for the models. I used the Schwarz information criterion for large samples (above 100 observations) and the Akaike information criterion for small samples (below 100 observations) and included the significant lags in the error correction models.

I also tested for stationarity. A time series is stationary if its statistical properties are constant over time (Wooldridge, 2015). In many linear models, using non-stationary variables leads to spurious results, if the variables are not cointegrated. Macroeconomic time series tend to be non-stationary but usually, they can be made stationary by differencing, for example. In case of the cost of borrowing indicators and the Euribor rates, first differences are stationary, with a few exceptions. In countries, where the first difference of the cost of borrowing indicator was not stationary, I reduced the number of lags suggested by the information criterion (Schwartz criterion mainly, since I have large samples) and with fewer lags stationarity was obtained.

4.2.2. Error correction models with dummy variable and interaction term

I ran the error correction models separately for each country, where the cost of borrowing indicators were cointegrated with one or more maturities of the Euribor. For an effectively working transmission mechanism through the interest rate channel the coefficient of the Euribor has to be positive both in the long-term and in the short-term models. Furthermore, the error correction term has to be negative and statistically significant. A positive sign means that there is no adjustment to the equilibrium value.

Results of the long-term equations of the error correction models in the corporate sector are summarized by *Table 6*. I have quite large samples, more than 200 observations for the entire period, except for Cyprus. $ß_1$ represents the coefficient of the Euribor and it can be seen that it is smaller than 1 in all cases, so the changes in the Euribor are not fully transmitted into the corporates' cost of borrowing indicator. $ß_1$ is the highest, above 0.8, in Germany and in the Netherlands. I selected the maturities of the final models based on the fastest transmission.

Table 6: Results of the long-term equations of the error correction models in the corporate sector

Country	**ß$_1$**	**Adjusted R-squared**	**Number of observations**	**Maturity of Euribor**
Austria	0.7724*** (0.000)	0.9819	234	3-month
Belgium	0.7440*** (0.000)	0.9823	234	3-month
Cyprus	0.7921*** (0.000)	0.4860	173	6-month
Estonia	0.7181*** (0.000)	0.8615	206	12-month
Finland	0.7321*** (0.000)	0.9760	234	3-month
France	0.7534*** (0.000)	0.9809	230	12-month
Germany	0.8279*** (0.000)	0.9687	230	12-month
Ireland	0.6530*** (0.000)	0.9213	234	3-month
Luxembourg	0.7740*** (0.000)	0.9812	234	3-month
Netherlands	0.8166*** (0.000)	0.9688	230	12-month
Portugal	0.7180*** (0.000)	0.5883	230	12-month
Slovenia	0.6440*** (0.000)	0.5137	230	12-month
Euro Area	0.7709*** (0.000)	0.9560	230	12-month

Note: ***Significant at the 1 percent level. P-values are given in parentheses.
Source: Estimation by the author based on ECB data

The final lag structure of the short-term error correction models with dummy variable and interaction term in the corporate sector is presented by *Table 7*. In five countries, one or more lags of the dependent variable proved to be significant. Regarding the Euribor, one or more lags (usually the first one) are significant everywhere, except for Germany. The first lag of the Euribor is interacted with the dummy variable, so I expected it to be significant in every case. However, in Cyprus and in Germany it is not significant.

Table 7: The final lag structure of the short-term equations of the error correction models with dummy variable and interaction term in the corporate sector

Country	**Significant lags of cost of borrowing**	**Significant lags of Euribor**
Austria		1st
Belgium	3rd, 12th	1st
Cyprus	7th	6th
Estonia		1st
Finland	12th	1st, 2nd
France	3rd	1st
Germany	6th	
Ireland		1st, 3rd
Luxembourg		1st
Netherlands		1st
Portugal		1st
Slovenia		1st
Euro Area		1st

Source: Estimation by the author based on ECB data

Table 8 summarizes the results of the short-term ECMs in the corporate sector. The coefficients of the lagged dependent variables, β_i move in a narrow range, roughly between 0.1 and 0.2. The Euribor and/or its lags are significant in every country and in the Euro Area as well. Their coefficients, γ_i vary mainly between 0.1 and 0.6. The error correction term is negative and statistically significant, as it should be. The value of λ is between -0.04 and -0.4, which illustrates considerable differences among Euro Area members regarding the speed of adjustment. λ is the highest in Finland, Ireland and Estonia and it is the lowest in Portugal, Slovenia and Cyprus. The outcomes show some signs of a North-South difference but it is not yet obvious. These results indicate that overall, the interest rate channel of the transmission mechanism was working in the examined period. The models were run from the first available data point (January 2003 in most cases) until the point at which the Euribor was negative. This was February 2022, May 2022 and June 2022 for the 12-month, 6-month and 3-month Euribor respectively.

The dummy variable for negative interest rates is significant in five countries and in the Euro Area, has a negative effect but its value is small. Meanwhile the coefficient of the interaction term, ζ, is quite high and has a negative sign in all of the six countries and in the Euro Area, where it is statistically significant. The interaction term shows the additional effect of the changes in the Euribor on the changes in corporates' cost of borrowing when interest rates are negative. The results of these estimations, that ζ is not zero and significant, mean that in some countries, the pass-through changes in the corporate sector, when interest rates become negative. The negative sign of the interaction variable indicates that the transmission mechanism is hindered by negative rates. The sign of the dummy variable is also negative, which points to the same direction. Based on the estimated ECMs, in most of the countries, negative interest rates influence the transmission mechanism (the dummy variable and/or the interaction term is significant) and their effect is negative.

Adjusted R-squared varies in a wide range, from 6 percent to 74 percent, which means that the variables included in the models explain a different proportion of the variance in corporates' cost of borrowing. The number of observations is above 200 in every country, except for Cyprus.

Table 8: Results of the short-term equations of the error correction models with dummy variable and interaction term in the corporate sector

Country	Lags of cost of borrowing	Euribor	Lags of Euribor	Error correction term	Negative interest rate dummy	Interaction term	Adjusted R-squared	Observations
Austria		0.5252*** (0.000)	0.1203* (0.056)	-0.2518*** (0.000)	-0.0027 (0.818)	-0.6775** (0.047)	0.5870	232
Belgium	0.1516*** (0.001) 0.0951** (0.018)	0.5605*** (0.000)	0.1368** (0.017)	-0.1617*** (0.000)	-0.0017 (0.877)	-0.2385 (0.434)	0.6299	221
Cyprus	0.2115*** (0.005)		0.1147 (0.496) 0.3086* (0.058)	-0.0941** (0.010)	-0.1653** (0.030)	0.1557 (0.845)	0.0927	166
Estonia		0.6014** (0.021)	-0.4840* (0.068)	-0.3749*** (0.000)	0.0072 (0.886)	-1.0111 (0.337)	0.2217	205
Finland	0.1439** (0.017)		0.4761*** (0.000) 0.2172* (0.064)	-0.4303*** (0.000)	0.0260 (0.247)	0.4915 (0.375)	0.3227	222
France	0.1846*** (0.001)		0.3240*** (0.000)	-0.2130*** (0.000)	-0.0127 (0.329)	-0.6592** (0.014)	0.4174	227
Germany	0.0977** (0.047)	0.6184*** (0.000)	-0.0535 (0.385)	-0.1343*** (0.000)	-0.0230* (0.074)	-0.4175* (0.096)	0.5238	223
Ireland			0.4525*** (0.001) 0.2437* (0.074)	-0.3835*** (0.000)	-0.0041 (0.901)	-1.3776* (0.095)	0.2354	231
Luxembourg			0.4250*** (0.000)	-0.2574*** (0.000)	-0.0062 (0.763)	-0.2296 (0.653)	0.1556	233

Country	Lags of cost of borrowing	Euribor	Lags of Euribor	Error correction term	Negative interest rate dummy	Interaction term	Adjusted R-squared	Observations
Netherlands			0.4972*** (0.000)	-0.1430*** (0.000)	-0.0349* (0.059)	-0.5756* (0.095)	0.3057	229
Portugal			0.4967*** (0.000)	-0.0354** (0.021)	-0.0639** (0.036)	-1.0136* (0.056)	0.1540	229
Slovenia			0.3019** (0.015)	-0.0498*** (0.009)	-0.0647* (0.098)	-0.4673 (0.513)	0.0557	229
Euro Area		0.4831*** (0.000)	0.1450*** (0.000)	-0.0548*** (0.000)	-0.0191** (0.022)	-0.4499*** (0.004)	0.7397	228

Note: Significant at the 1 percent (***), at the 5 percent (**) and at the 10 percent (*) level. P-values are given in parentheses.
Source: Estimation by the author based on ECB data

Table 9 illustrates the results of the long-term error correction models in the household sector. $ß_1$ is lower than 1 in all countries, so changes in the Euribor are not fully transmitted into households' cost of borrowing. In the household sector, $ß_1$ is typically lower than in the corporate sector, which is reasonable, since transmission tends to be weaker in the household sector (Claeys, 2021). The number of observations exceeds 200 in all cases, except for Cyprus and Malta. I chose the maturities again based on the fastest transmission.

Table 9: Results of the long-term equations of the error correction models in the household sector

Country	**$ß_1$**	**Adjusted R-squared**	**Number of observations**	**Maturity of Euribor**
Austria	0.7203*** (0.000)	0.9114	234	3-month
Cyprus	0.7742*** (0.000)	0.5360	174	3-month
Estonia	0.6476*** (0.000)	0.9198	210	3-month
Finland	0.8055*** (0.000)	0.9768	233	6-month
France	0.6841*** (0.000)	0.7515	230	12-month
Germany	0.8134*** (0.000)	0.8624	230	12-month
Greece	0.4593*** (0.000)	0.7515	233	6-month
Italy	0.7145*** (0.000)	0.8143	234	3-month
Luxembourg	0.6811*** (0.000)	0.9734	234	3-month
Malta	0.4736*** (0.000)	0.8664	170	12-month
Netherlands	0.6063*** (0.000)	0.7253	230	12-month
Slovakia	1.0874*** (0.000)	0.6883	170	12-month
Slovenia	0.8962*** (0.000)	0.9411	230	12-month

Note: ***Significant at the 1 percent level. P-values are given in parentheses.
Source: Estimation by the author based on ECB data

Table 10 shows the final lag structure of the short-term error correction models in the household sector. In most of the cases, one or more lags of the dependent variable is significant. The first lag of the Euribor, which is also in the interaction term, is not significant in Cyprus and Finland.

Table 10: The final lag structure of the short-term equations of the error correction models with dummy variable and interaction term in the household sector

Country	**Significant lags of cost of borrowing**	**Significant lags or Euribor**
Austria	9th, 12th	1st, 3rd
Cyprus		4th, 10th
Estonia	12th	1st
Finland	1st	11th
France	1st, 2nd	1st
Germany	1st	1st
Greece		1st
Italy	1st, 2nd, 3rd	1st
Luxembourg	3rd	1st
Malta		1st
Netherlands	2nd	1st
Slovakia		1st
Slovenia		1st, 12th

Source: Estimation by the author based on ECB data

Results of the short-term ECMs in the household sector are presented by *Table 11*. Lagged values of the dependent variable are significant in more countries, than in the corporate sector and β_i varies in a larger range, from 0.11 to 0.36. The coefficients of the Euribor and its lags, γ_i show a considerable difference across countries, they change between 0.04 and 0.68. The error correction term is negative and it is significant in every country. Its coefficient, λ is markedly smaller than in the corporate sector and major distinctions can be observed across Eurozone members. No difference based on geographical location can be identified. The value of λ is the highest in Estonia and Malta and the lowest in Germany and Italy. The negative interest rate dummy is significant in four countries and its value is quite small. The interaction term proved to be significant in five other Eurozone members (the only exception is France, where both are significant) and surprisingly its sign changes across countries. It is negative in Finland, France and Slovenia, while it is positive in Germany and Greece. The coefficient, ζ varies in a large range, from -0.43 to 0.65. The outcomes of the estimated ECMs point to the direction that negative interest rates have different effects on households cost of borrowing across Euro Area members. In most of the countries, they have some impact on the transmission mechanism (the dummy variable and/or the interaction term is significant) and it seems to be rather negative. However, in two countries (Germany and Greece), they have additional positive effects.

Adjusted R-squared varies between 0.1 and 0.8, which again indicates major differences among the countries. It is the highest in Finland and the lowest in Greece. The number of observations is above 150 and it exceeds 200 in most of the cases.

Table 11: Results of the short-term equations of the error correction models with dummy variable and interaction term in the household sector

Country	Lags of cost of borrowing	Euribor	Lags of Euribor	Error correction term	Negative interest rate dummy	Interaction term	Adjusted R-squared	Observations
Austria	0.1233** (0.029) 0.1319** (0.014)		0.2631*** (0.000) 0.1220** (0.013)	-0.0834*** (0.001)	-0.0062 (0.583)	0.3266 (0.203)	0.4778	222
Cyprus			-0.1094 (0.177) 0.2443*** (0.004) 0.1562** (0.037)	-0.0561*** (0.001)	-0.0739** (0.011)	0.4410 (0.349)	0.1661	174
Estonia	0.1084** (0.045)	0.3597*** (0.000)	0.1475** (0.046)	-0.1074*** (0.000)	-0.0038 (0.794)	0.2555 (0.514)	0.4096	197
Finland	0.1497** (0.021)	0.6778*** (0.000)	0.0383 (0.549) 0.0405* (0.094)	-0.0462** (0.015)	-0.0075 (0.288)	-0.3689** (0.016)	0.8411	221
France	0.3587*** (0.000) 0.1619*** (0.006)		0.0802*** (0.000)	-0.0344*** (0.000)	-0.0287*** (0.000)	-0.2402** (0.041)	0.5784	228
Germany	0.2713*** (0.000)	0.1032*** (0.006)	0.1784*** (0.000)	-0.0137* (0.079)	0.0011 (0.891)	0.2725* (0.095)	0.4869	228
Greece			0.1381* (0.056)	-0.0792*** (0.000)	0.0109 (0.560)	0.6450* (0.090)	0.0960	232

Country	**Lags of cost of borrowing**	**Euribor**	**Lags of Euribor**	**Error correction term**	**Negative interest rate dummy**	**Interaction term**	**Adjusted R-squared**	**Observations**
Italy	0.1597** (0.020) 0.1657** (0.011) 0.1591** (0.012)		0.1902*** (0.000)	-0.0209* (0.054)	-0.0047 (0.681)	0.3097 (0.205)	0.3939	231
Luxembourg	0.1647*** (0.003)	0.2471*** (0.000)	0.2539*** (0.000)	-0.0853*** (0.005)	0.0080 (0.446)	0.0658 (0.827)	0.4618	230
Malta			0.3410*** (0.000)	-0.1032** (0.016)	-0.0126 (0.560)	-0.2215 (0.586)	0.1067	170
Netherlands	0.1959*** (0.001)		0.1988*** (0.000)	-0.0263*** (0.001)	-0.0226** (0.018)	-0.0853 (0.597)	0.3311	228
Slovakia			0.1366** (0.012)	-0.0375*** (0.000)	-0.0354* (0.067)	0.1282 (0.652)	0.1247	170
Slovenia		0.1625*** (0.001)	0.4879*** (0.000) 0.0964*** (0.003)	-0.0508*** (0.002)	-0.0047 (0.623)	-0.4298** (0.033)	0.6749	217

Note: Significant at the 1 percent (***), at the 5 percent (**) and at the 10 percent (*) level. P-values are given in parentheses.
Source: Estimation by the author based on ECB data

4.2.3. Two-period error correction models

In order to better understand interest rate transmission at negative rates, I followed the analysis with estimations of two-period error correction models. I divided the sample I used in the previous section into two time periods. In the first period the Euribor is positive, while in the second one it is negative. The time frames of the analysis are illustrated by *Table 12*.

Table 12: Time frames of the analysis

Maturity	**First period**	**Second period**
3-month Euribor	January 2003 – April 2015	May 2015 – June 2022
6-month Euribor	January 2003 – October 2015	November 2015 – May 2022
12-month Euribor	January 2003 – January 2016	February 2016 – February 2022

Source: Constructed by the author based on ECB data.

The long-term error correction models were not changed compared to the previous section (*Equation 5*). The results are summarized by *Table 6* and *Table 9.*

The short-term equation is estimated without the dummy variable and the interaction term:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta y_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta x_{t-1} + \lambda e_{t-1} \qquad (7)$$

Table 13 summarizes the final lag structure of the two-period short-term ECMs in the corporate sector. In the first period the number of significant lags is higher than in the second one. In some cases, especially in the second period, only the first difference of the Euribor remained significant in the final model.

Table 13: The final lag structure of the two-period short-term equations of the error correction models in the corporate sector

Country	**Significant lags of cost of borrowing in the 1st period**	**Significant lags of Euribor in the 1st period**	**Significant lags of cost of borrowing in the 2nd period**	**Significant lags of Euribor in the 2nd period**
Austria		2nd		
Belgium	3rd	1st	3rd	
Cyprus		7th		
Estonia				
Finland		2nd		
France	3rd		3rd	
Germany	3rd		3rd	
Ireland				
Luxembourg				
Netherlands		2nd		
Portugal				
Slovenia		1st		
Euro Area	3rd	5th		

Note: Empty cells mean that there are no significant lags in the final models. However, the first difference of the Euribor can be significant.
Source: Estimation by the author based on ECB data

Table 14 illustrates the results of the two-period short-term error correction models in the corporate sector. In the first period, when the Euribor was positive, the speed of adjustment, λ, varies in a wide range, between -0.03 and -0.34, and the transmission is not complete, as *Table 6* shows. These findings again support the differences among Euro Area member states. The value of λ is quite low in the case of Portugal, Slovenia and the Euro Area, which means that adjustment is slow in these countries. The sign of λ is negative, as it should be and it is significant in every country. The first difference of the Euribor is also significant in every country, has a positive sign and its coefficient varies between 0.31 and 0.76. In some cases, a lag of the dependent variable and/or the Euribor is also significant and has a positive sign. The variables included in the analysis explain about 10 – 80 percent of the variance in the dependent variable. The explanatory power of the model is the lowest in Cyprus and Slovenia and the highest in the Euro Area and Austria. The number of observations is above 100, except for Cyprus. In the positive interest rate environment, the results show, on average, a moderate speed of adjustment to the equilibrium value and point to an effectively working interest rate channel in most of the countries analyzed.

Table 14: Results of the two-period short-term equations of the error correction models in the corporate sector

Country	**Lag of cost of borrowing**	**Euribor**	**Lag of Euribor**	**Error correction term**	**Adjusted R-squared**	**Observations**
Austria 1st period		0.5535*** (0.000)	0.1858*** (0.000)	-0.2130*** (0.000)	0.7017	145
Austria 2nd period			-0.4801 (0.124)	-0.5108*** (0.000)	0.2549	86
Belgium 1st period	0.1201** (0.032)	0.5509*** (0.000)	0.1695** (0.018)	-0.1543*** (0.000)	0.6262	144
Belgium 2nd period	0.3111*** (0.004)	0.2924** (0.039)		-0.1840*** (0.004)	0.2066	86
Cyprus 1st period			0.3285* (0.083)	-0.0784** (0.028)	0.0811	87
Cyprus 2nd period			0.2589 (0.724)	-0.1315** (0.012)	0.0591	86
Estonia 1st period		0.3149* (0.090)		-0.2992*** (0.000)	0.2053	132
Estonia 2nd period		-0.3490 (0.726)		-0.5025*** (0.000)	0.2430	73
Finland 1st period		0.6971*** (0.000)	0.1997** (0.014)	-0.3087*** (0.000)	0.5009	145
Finland 2nd period		0.6747 (0.137)		-0.8424*** (0.000)	0.3944	86
France 1st period	0.1923*** (0.000)	0.4944*** (0.000)		-0.1849*** (0.000)	0.6698	153
France 2nd period	0.2403** (0.030)	-0.5900*** (0.008)		-0.1774*** (0.009)	0.1950	73
Germany 1st period	0.1245** (0.025)	0.5711*** (0.000)		-0.0983*** (0.001)	0.6177	153
Germany 2nd period	0.2720** (0.013)	0.3951* (0.076)		-0.2813*** (0.001)	0.2234	73
Ireland 1st period		0.7588*** (0.000)		-0.1781*** (0.000)	0.3744	147
Ireland 2nd period		0.4333 (0.650)		-0.6624*** (0.000)	0.3133	86
Luxembourg 1st period		0.7205*** (0.000)		-0.3443*** (0.000)	0.3809	147
Luxembourg 2nd period		0.3694 (0.149)		-0.3885*** (0.000)	0.1612	86
Netherlands 1st period		0.5513*** (0.000)	0.1361** (0.026)	-0.1338*** (0.001)	0.5130	154
Netherlands 2nd period			-0.4853 (0.162)	-0.3233*** (0.000)	0.1594	73

Country	**Lag of cost of borrowing**	**Euribor**	**Lag of Euribor**	**Error correction term**	**Adjusted R-squared**	**Observations**
Portugal 1st period		0.4232*** (0.000)		-0.0337** (0.049)	0.1422	156
Portugal 2nd period		-0.3650 (0.414)		-0.1356*** (0.005)	0.0893	73
Slovenia 1st period			0.3286*** (0.002)	-0.0298* (0.068)	0.0958	146
Slovenia 2nd period		0.6577 (0.372)		-0.4007*** (0.000)	0.2323	82
Euro Area 1st period	0.1033** (0.030)	0.5767*** (0.000)	0.0716** (0.028)	-0.0401** (0.022)	0.7934	151
Euro Area 2nd period		0.1121 (0.322)		-0.1412*** (0.003)	0.1091	73

Note: Significant at the 1 percent (***), at the 5 percent (**) and at the 10 percent (*) level. P-values are given in parentheses.
Source: Estimation by the author based on ECB data

In the second period, when the Euribor was negative, λ is typically higher in absolute terms, than in the first period, however, in most cases the Euribor loses its significance and the adjusted R-squared falls drastically. The results indicate that in most countries the relationship between corporates' cost of borrowing and the Euribor, which exists at positive interest rates, collapses when the Euribor becomes negative. However, in the case of Belgium, France, and Germany the relationship does not fall apart. The value of λ is similar to the first period in Belgium and France, while it is considerably higher in Germany.

Table 15 shows that in most of the countries, households' cost of borrowing depends on its own lags and/or on the lags of the Euribor in the first period. In the second period, the number of significant lags is lower, especially in the case of the Euribor.

Table 15: Final lag structure of the two-period short-term equations of the error correction models in the household sector

Country	Significant lags of cost of borrowing in the 1st period	Significant lags of Euribor in the 1st period	Significant lags of cost of borrowing in the 2nd period	Significant lags of Euribor in the 2nd period
Austria	3rd	1st	3rd	1st
Cyprus		7th		
Estonia				1st
Finland	1st			
France	1st, 2nd	2nd	3rd	
Germany	1st		1st, 3rd	1st
Greece	2nd			
Italy	1st, 3rd		2nd, 3rd	
Luxembourg		1st,2nd	2nd	
Malta				
Netherlands	1st	1st		
Slovakia		1st		
Slovenia		1st		

Note: Empty cells mean that there are no significant lags in the final models.
Source: Estimation by the author based on ECB data

Table 16 summarizes the results of the two-period short-term error correction models in the household sector. In the first period, when the Euribor was positive, the speed of adjustment, λ, is considerably slower than in the corporate sector. These results are in line with the literature (Claeys, 2021). λ is significant and has a negative sign in every country, as expected. Its value varies between -0.02 and -0.2. The Euribor and/or its lags are also significant and have a positive sign, however, their coefficients fluctuate in a wide range (from 0.1 to 0.7), which again highlights the differences among Euro Area member states. The variables included in the models explain around 50 percent of the variance in the dependent variable, on average, but the value of the adjusted R-squared differs considerably across countries. The number of observations is above 100 in most of the cases.

Table 16: Results of the two-period short-term equations of the error correction models in the household sector

Country	Lag of cost of borrowing	Euribor	Lag of Euribor	Error correction term	Adjusted R-squared	Observations
Austria 1st period	0.2000*** (0.005)		0.2616*** (0.000)	-0.1066*** (0.001)	0.4797	144
Austria 2nd period	0.5275*** (0.000)		0.4868*** (0.002)	-0.0268 (0.175)	0.3330	86
Cyprus 1st period			0.1961* (0.061)	-0.0689*** (0.003)	0.1559	88
Cyprus 2nd period		0.1858 (0.446)		-0.0521** (0.010)	0.0702	86
Estonia 1st period		0.5036*** (0.000)		-0.0812*** (0.001)	0.4277	123
Estonia 2nd period			0.6131** (0.029)	-0.0734* (0.070)	0.0920	86
Finland 1st period	0.1684*** (0.000)	0.7065*** (0.000)		-0.0495** (0.024)	0.8480	152
Finland 2nd period		0.5135*** (0.000)		-0.0301 (0.282)	0.4311	79
France 1st period	0.3107*** (0.000) 0.1847*** (0.005)		0.1514*** (0.000)	-0.0207*** (0.006)	0.6824	155
France 2nd period	0.3002*** (0.001)	0.2671*** (0.007)		-0.0937*** (0.000)	0.3703	73
Germany 1st period	0.3841*** (0.000)	0.2086*** (0.000)		-0.0186** (0.045)	0.4589	155
Germany 2nd period	0.2150* (0.051) 0.1807* (0.087)		0.5334*** (0.000)	-0.0350 (0.135)	0.3286	73
Greece 1st period	0.1475* (0.059)	0.1474** (0.028)		-0.0634*** (0.004)	0.1123	151
Greece 2nd period			0.6344 (0.163)	-0.2752*** (0.000)	0.1543	79
Italy 1st period	0.2904*** (0.000) 0.1750** (0.011)	0.2301*** (0.000)		-0.0248** (0.033)	0.5087	144
Italy 2nd period	0.2007* (0.057) 0.2244** (0.042)	0.7553*** (0.000)		-0.0287 (0.211)	0.2450	86

Country	Lag of cost of borrowing	Euribor	Lag of Euribor	Error correction term	Adjusted R-squared	Observations
Luxembourg 1st period		0.2486*** (0.000)	0.1815** (0.028) 0.1816*** (0.005)	-0.0967** (0.018)	0.4926	145
Luxembourg 2nd period	0.2875** (0.014)	0.5323*** (0.000)		-0.0327 (0.328)	0.2232	86
Malta 1st period		0.4922*** (0.000)		-0.2013*** (0.002)	0.3034	96
Malta 2nd period			0.5788 (0.170)	-0.0658 (0.213)	0.0209	73
Netherlands 1st period	0.4207*** (0.000)		0.1496*** (0.000)	-0.0200*** (0.006)	0.5580	156
Netherlands 2nd period			0.2140 (0.325)	-0.0345 (0.252)	0.0075	73
Slovakia 1st period			0.1406** (0.031)	-0.0343*** (0.004)	0.1289	97
Slovakia 2nd period			0.2432 (0.247)	-0.1089*** (0.000)	0.1804	73
Slovenia 1st period		0.1041* (0.067)	0.5150*** (0.000)	-0.0688*** (0.000)	0.6668	155
Slovenia 2nd period		0.5398*** (0.000)		0.0153 (0.578)	0.2034	73

Note: Significant at the 1 percent (***), at the 5 percent (**) and at the 10 percent (*) level. P-values are given in parentheses. In the second period, in the case of Greece, the first lag of the 6-month Euribor is shown in the table, but it is not significant and is therefore not included in *Table 15*.
Source: Estimation by the author based on ECB data

In the second period, when the Euribor was negative, the error correction term is significant only in five countries, implying that there is no adjustment to the equilibrium value in the other eight countries. In a number of cases, the Euribor or its lags also lose their significance. There are only two countries where the Euribor and the error correction term are both significant and have the correct signs, in Estonia and in France. The speed of adjustment to the equilibrium value is similar to the first period in Estonia and it is somewhat higher in France. The adjusted R-squared also falls remarkably compared to the first period, even in these two countries. The results indicate that the relationship between households' cost of borrowing and the Euribor, which exists in the first period, usually collapses when the Euribor becomes negative.

4.2.4. Extended error correction models

European monetary policy has gone through important changes after the global financial crisis and the European sovereign debt crisis. Unconventional tools became increasingly important and they amended interest rate policy. Taking this into account, I extended the two-period error correction models with several other variables that may have a role in the transmission mechanism. I tried to capture the macroeconomic environment with inflation, industrial production, the exchanges rate, the money supply and unemployment[6]. I also tested the effects of the ECB's assets and its two-tier system for remunerating excess reserve holdings on the cost of borrowing indicators. The additional variables, their measurement and the expected signs are presented by *Table 17*. Determination of the expected sign is based on economic theories. The two-tier system was introduced in September 2019 in order to support the transmission of monetary policy, while preserving the accommodative stance with negative interest rates. The two-tier system was used to exempt part of a credit institution's current account holdings (in excess of minimum reserve requirements) from the negative deposit facility rate (ECB, 2019). I expected the sign of the two-tier system dummy to be positive. Since it was introduced to support the transmission mechanism of monetary policy, its role was to make the further reduction of borrowing costs by banks possible.

Table 17: Variables included in the extended error correction models[7]

Variable	Measurement	Expected sign
ECB assets	Millions of Euros	Negative
Exchange rate	Euro/US dollar	Positive
Inflation	Index, 2015=100, all items HICP	Negative
Industrial production	Index, 2015=100	Negative
Money supply (M1)	Millions of Euros	Negative
Unemployment	Percentage	Positive
Two-tier system dummy	Dummy variable	Positive

Source: Constructed by the author based on ECB and Eurostat data

Table 18 provides a summary of the additional variables in the extended error correction models. In the case of inflation, industrial production and unemployment, only those countries

---

[6] I did not want to reduce the number of observations, therefore I could only use monthly data. Consequently an important macroeconomic indicator, GDP is not included in the models, since it is published quarterly.

[7] The extended error correction models are estimated in first differences.

where these indicators were significant in the models are presented in *Table 18*. The full table can be found in the Appendix (*Table 32, 33* and *34*).

Table 18: Summary statistics - Extended error correction models

Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
ECB assets	235	2 950 940	2 186 135	2 097 581	778 537	8 825 698
Exchange rate	235	1.24	1.23	0.12	1.02	1.58
Money supply (M1)	235	5 819 102	5 072 922	2 498 260	2 454 715	11 627 401
Inflation						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Belgium	235	96.34	97.82	10.54	77.51	122.82
France	235	96.70	98.56	7.65	81.87	114.94
Germany	235	96.40	97.40	8.46	82.00	119.00
Italy	235	95.28	98.20	8.23	78.50	114.10
Portugal	235	96.28	98.78	7.47	80.75	114.39
Slovenia	235	95.35	98.91	9.71	74.64	119.63
Euro Area	235	96.14	98.36	8.44	80.14	117.14
Industrial production						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Austria	235	97.76	97.10	12.83	73.30	130.70
Estonia	235	92.96	94.00	20.15	57.30	130.60
France	235	103.10	101.70	6.16	67.80	115.90
Greece	235	118.44	111.40	17.02	95.30	149.90
Ireland	235	80.63	65.30	27.79	49.70	174.60
Italy	235	109.35	105.80	11.28	58.20	133.30
Portugal	235	106.49	103.40	9.80	74.40	128.30
Slovenia	235	102.76	97.30	14.53	81.20	136.80
Unemployment						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Austria	235	5.53	5.50	0.71	3.90	7.90
France	235	8.99	9.00	0.91	7.10	10.50
Malta	235	5.62	6.00	1.40	2.90	8.50
Slovakia	235	11.56	12.00	3.82	5.70	19.10

Source: Constructed by the author based on ECB and Eurostat data.

Similarly to the previous section, I have divided the sample into positive and negative interest rate periods. The time frame of the analysis is the same as shown in *Table 12*. The long-term error correction models were not changed compared to the previous sections (*Equation 5*). The results are summarized by *Table 6* and *Table 9*.

In the first period, the short-term equation of the previously estimated error correction model is extended to include other independent variables as follows:

$$\Delta CB_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta CB_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta EUR_{t-1} + \sum_{i=1}^{n} \zeta_i \Delta ECB_{t-1} + \ldots$$
$$\ldots + \sum_{i=1}^{n} \eta_i \Delta FX_{t-1} + \sum_{i=1}^{n} \theta_i \Delta CPI_{t-1} + \sum_{i=1}^{n} \iota_i \Delta IND_{t-1} + \sum_{i=1}^{n} \kappa_i \Delta M1_{t-1} + \ldots$$
$$\ldots + \sum_{i=1}^{n} \mu_i \Delta UNRATE_{t-1} + \lambda e_{t-1} + \varepsilon_t \tag{8}$$

The variables that are included in the equation are the following: cost of borrowing (CB), Euribor (EUR), ECB assets (ECB), exchange rate (FX), inflation (CPI), industrial production (IND), money supply (M1) and unemployment rate (UNRATE).

The dummy variable for the two-tier system ($TT_{xt < 0}$) is added to *Equation 8* in the second period:

$$\Delta CB_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta CB_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta EUR_{t-1} + \sum_{i=1}^{n} \zeta_i \Delta ECB_{t-1} + \ldots$$
$$\ldots + \sum_{i=1}^{n} \eta_i \Delta FX_{t-1} + \sum_{i=1}^{n} \theta_i \Delta CPI_{t-1} + \sum_{i=1}^{n} \iota_i \Delta IND_{t-1} + \sum_{i=1}^{n} \kappa_i \Delta M1_{t-1} + \ldots$$
$$\ldots + \sum_{i=1}^{n} \mu_i \Delta UNRATE_{t-1} + + \nu TT_{xt < 0} + \lambda e_{t-1} + \varepsilon_t \tag{9}$$

Table 19 presents the final lag structure of the extended error correction models. It can be seen that several lagged values of the variables are significant in the first time period, when the Euribor was positive.

Table 19: Final lag structure of the extended error correction models in the corporate sector in the first period

Country	Cost of borrowing	Euribor	ECB assets	Exchange rate	Inflation	Industrial production
Austria	3rd	2nd	1st, 3rd	3rd		1st
Belgium		1st			5th	
Estonia			1st			
Finland		2nd	1st			
France	3rd	2nd	1st			
Germany	3rd		1st		7th	
Ireland						8th
Luxembourg				2nd		
Netherlands		2nd	2nd			
Portugal				5th	3rd	5th
Euro Area	3rd	1st	3rd			

Note: In the case of Cyprus and Slovenia the results correspond to the outcomes of the two-period non-extended ECMs, so they are omitted from the table.
Source: Estimation by the author based on ECB and Eurostat data

Results of the extended error correction models in the corporate sector in the first period are summarized by *Table 20*[8]. Out of the six additional explanatory variables that were included in the ECMs in the first period, usually only one or two remained significant in the final models. The exchange rate has a considerable effect on corporates' cost of borrowing in four countries. The assets of the ECB proved to be significant in six countries and in the Euro Area, however, its high coefficient is rather explained by the type of measurement. Inflation and industrial production also influence cost of borrowing in some countries but they have a small effect in every case. Overall, the results are quite similar to the two-period non-extended ECMs. There are no significant differences between the coefficients of the lagged dependent variables, the Euribor and its lags and the speed of adjustment is also around the value estimated with the simple models. In the case of Cyprus and Slovenia none of the additional variables proved to be significant in the final model, so they are omitted from *Table 19* and *Table 20*. The adjusted R-squared is obviously higher, since more explanatory variables are included in the models.

---

[8] Results can only be presented separately for positive and negative interest rate periods due to the larger number of independent variables.

Table 20: Results of the extended error correction models in the corporate sector in the first period

Country	Lag of cost of borrowing	Euribor	Lag of Euribor	Error correction term	Exchange rate	Inflation	Industrial production	ECB assets	Adjusted R-squared	Observations
Austria	0.1041** (0.049)	0.4968*** (0.000)	0.1269** (0.027)	-0.2023*** (0.000)	0.3864* (0.091)		-0.0091* (0.073)	-2.0400* (0.064) -3.1000** (0.010)	0.7421	144
Belgium		0.5240*** (0.000)	0.2447*** (0.000)	-0.1196*** (0.003)	0.5315** (0.025)	-0.0356*** (0.000)			0.6758	142
Estonia		0.1911 (0.331)		-0.3169*** (0.000)				-7.6700* (0.080)	0.2181	132
Finland		0.6150*** (0.000)	0.2517*** (0.003)	-0.3123*** (0.000)				-4.2300** (0.027)	0.5147	145
France	0.1470*** (0.008)	0.4231*** (0.000)	0.1173** (0.030)	-0.1693** (0.000)				-2.4900** (0.011)	0.6875	153
Germany	0.1553*** (0.005)	0.5082*** (0.000)		-0.1212*** (0.000)		-0.0297* (0.090)		-3.4500*** (0.001)	0.6323	149
Ireland		0.7804*** (0.000)		-0.1484*** (0.002)			-0.0140*** (0.000)		0.4432	139
Luxembourg		0.6865*** (0.000)		-0.3540*** (0.000)	0.9067** (0.028)				0.4011	145
Netherlands		0.4938*** (0.000)	0.1467** (0.015)	-0.1620*** (0.000)				-3.7900*** (0.006)	0.5336	154
Portugal		0.4108*** (0.000)		-0.0340** (0.041)	0.9046* (0.070)	-0.0717** (0.022)	-0.0101** (0.048)		0.1980	151
Euro Area	0.1479*** (0.000)	0.4890*** (0.000)	0.0906** (0.026)	-0.0445** (0.012)				-1.3700** (0.047)	0.8020	153

Note: Significant at the 1 percent (***), at the 5 percent (**) and at the 10 percent (*) level. P-values are given in parentheses. In the case of Cyprus and Slovenia the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table.

Source: Estimation by the author based on ECB and Eurostat data

The final lag structure of the extended error correction models in the corporate sector in the second period is presented by *Table 21*. Only a few lags are significant, mainly the lags of inflation.

Table 21: Final lag structure of the extended error correction models in the corporate sector in the second period

Country	**Euribor**	**ECB assets**	**Inflation**	**Industrial production**
Belgium			2nd, 5th	
Estonia				3rd
France		1st		
Netherlands	8th			
Portugal			8th	
Slovenia			13th	
Euro Area			2nd	

Note: In the case of Austria, Cyprus, Finland, Germany, Ireland and Luxembourg the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table.
Source: Estimation by the author based on ECB and Eurostat data

Table 22 presents the results of the second period, when the Euribor was negative. The results are again similar to the outcomes of the two-period non-extended ECMs. A notable difference is that in the case of France, the Euribor looses its significance in the extended model, while it becomes significant in the case of the Netherlands. In six countries and the Euro Area, the additional explanatory variables and the error correction term proved to be significant. However, the Euribor or its lags are only significant in Belgium and the Netherlands. In six countries, the results correspond to the outcomes of the non-extended ECMs, so they are omitted from *Table 21* and *Table 22*. The value of the adjusted R-squared falls substantially again compared to the first period. In Belgium, the speed of adjustment is similar to the first period, while it is higher in the Netherlands. However, even in these two countries, the adjusted R-squared is notably lower than in the first period. The coefficients of the additional variables are usually low[9], which means that they do not have a sizeable affect on corporates' cost of borrowing. The two-tier system dummy is significant in three countries but its sign is positive in Belgium, while in the Netherlands and Slovenia it is negative. Its magnitude is

---

[9] Except for the ECB assets, however, in this case, the high coefficient is rather explained by the type of measurement.

rather small, except for Slovenia, however, in that case λ is unusually high, while the Euribor is not significant, so the results of that model do not seem reasonable. To summarize, including additional explanatory variables in the error correction models typically do not alter the outcomes of the two-period non-extended models in the second period, when the Euribor was negative. A large part of the variance in cost of borrowing in the corporate sector cannot be captured with the addition of standard macroeconomic indicators used in this analysis.

Table 22: Results of the extended error correction models in the corporate sector in the second period

Country	Lag of cost of borrowing	Euribor	Lag of Euribor	Error correction term	Inflation	Money supply	Industrial production	ECB assets	Two-tier system dummy	Adjusted R-squared	Observations
Belgium		0.4569*** (0.001)		-0.1522** (0.011)	-0.0196*** (0.000) -0.0172*** (0.000)				0.0206** (0.019)	0.3717	86
Estonia		0.3414 (0.721)		-0.4760*** (0.000)		-0.0035** (0.014)	-0.0249** (0.016)			0.3365	73
France			0.1606 (0.528)	-0.2820*** (0.000)				-2.9800*** (0.003)		0.1808	73
Netherlands		0.5890** (0.037)	0.6960** (0.037)	-0.3722*** (0.000)		-0.0012*** (0.003)			-0.0602** (0.025)	0.2928	73
Portugal			-0.7724 (0.123)	-0.1271*** (0.005)	-0.0674*** (0.001)					0.2218	73
Slovenia		0.8492 (0.198)		-0.6517*** (0.000)	-0.1120** (0.019)				-0.1242** (0.038)	0.3557	73
Euro Area		0.1261 (0.240)		-0.1475*** (0.001)	-0.0257*** (0.004)					0.2019	73

Note: Significant at the 1 percent (***), at the 5 percent (**) and at the 10 percent (*) level. P-values are given in parentheses. In the case of Austria, Cyprus, Finland, Germany, Ireland and Luxembourg the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table.

Source: Estimation by the author based on ECB and Eurostat data

Table 23 shows the significant lagged variables in the household sector in the first period, when the Euribor was positive. In most countries, the lags of the dependent variable and the Euribor are significant. In four countries (Estonia, Luxembourg, the Netherlands and Slovakia), the additional variables did not prove to be significant in the first period, so they are omitted from *Table 23* and *Table 24*.

Table 23: Final lag structure of the extended error correction models in the household sector in the first period

Country	**Cost of borrowing**	**Euribor**	**ECB assets**	**Exchange rate**	**Inflation**	**Industrial production**	**Unemploy -ment**
Austria	3rd	1st					2nd
Cyprus		7th		2nd			
Finland	1st						
France	1st, 2nd	2nd			1st		
Germany	1st	1st		1st	3rd		
Greece	2nd	1st				1st	
Italy	1st, 2nd			1st	6th	3rd	
Malta							1st
Slovenia		1st, 5th	1st, 4th				

Note: In the case of Estonia, Luxembourg, the Netherlands and Slovakia the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table.
Source: Estimation by the author based on ECB and Eurostat data

Results of the extended error correction models in the household sector in the first period are presented by *Table 24*. As in the case of the corporate sector, considerable differences compared to the two-period non-extended ECMs cannot be observed in the household sector either. The coefficients of the lagged dependent variables and the Euribor are similar and the speed of adjustment does not differ substantially from the results of the simple models. Such as in the corporate sector, the exchange rate and the ECB assets have notable effects, while in addition to inflation and industrial production, unemployment also proved to be significant in some cases. Adjusted R-squared is again naturally higher than in the simple models.

Table 24: Results of the extended error correction models in the household sector in the first period

Country	Lag of cost of borrowing	Euribor	Lag of Euribor	Error correction term	Exchange rate	Inflation	Industrial production	ECB assets	Unem-ployment	Adjusted R-squared	Observations
Austria	0.1970*** (0.005)		0.2691*** (0.000)	-0.1096*** (0.000)					0.0041* (0.056)	0.4937	145
Cyprus			0.2423** (0.024)	-0.0691*** (0.003)	1.0013* (0.088)					0.1752	88
Finland	0.1803*** (0.000)	0.6964*** (0.000)		-0.0615*** (0.007)				-1.3700** (0.049)		0.8509	152
France	0.2932*** (0.000) 0.2050*** (0.002)		0.1554*** (0.000)	-0.0211*** (0.005)		-0.0170* (0.072)				0.6872	155
Germany	0.2743*** (0.000)		0.2549*** (0.000)	-0.0162* (0.075)		-0.0236* (0.070)				0.5246	154
Greece	0.1610** (0.032)		0.2134*** (0.002)	-0.0550** (0.011)			-0.0117*** (0.000) -0.0093*** (0.003)	-2.5200* (0.083)		0.1978	152
Italy	0.3337*** (0.000) 0.1645** (0.016)	0.2167*** (0.000)		-0.0272** (0.010)	0.4470*** (0.009)	-0.0333*** (0.000)	-0.0091*** (0.003)			0.5951	141
Malta		0.5209*** (0.000)		-0.1890*** (0.002)					0.0242*** (0.002)	0.3630	96
Slovenia			0.5380*** (0.000) 0.0731* (0.059)	-0.0712*** (0.000)				-3.2500*** (0.000) -1.9200** (0.043)		0.7142	152

Note: In the case of Estonia, Luxembourg, the Netherlands and Slovakia the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table.
Source: Estimation by the author based on ECB and Eurostat data

Table 25 shows the significant lags of the extended ECMs in the household sector in the second period, when the Euribor was negative. Only a few lags remained in the final models, mainly in the case of France and Germany. In seven countries, none of the additional variables proved to be significant, so they are omitted from *Table 25* and *Table 26.*

Table 25: Final lag structure of the extended error correction models in the household sector in the second period

Country	**Cost of borrowing**	**Euribor**	**Exchange rate**	**Inflation**	**Unemployment**
Estonia					
Finland					
France	1st, 2nd		1st	7th	
Germany	1st	1st		12th	
Slovakia					1st
Slovenia		1st			

Note: In the case of Austria, Cyprus, Greece, Italy, Luxembourg, Malta, the Netherlands the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table.
Source: Estimation by the author based on ECB and Eurostat data

Results of the extended error correction models in the second period are presented by *Table 26.* Compared to the simple models in the second period Euribor looses its significance in Estonia, however, λ becomes negative and significant in Slovenia. Otherwise the results do not considerably differ from the outcomes of the non-extended models. The error correction term and the Euribor are both significant in France and in Slovenia, while in the other countries only one of them is. The adjusted R-squared increases substantially in France, Slovakia and Slovenia, where more additional variables remain in the final models. The exchange rate has a notable effect on households' cost of borrowing in Estonia and France, while the coefficients of the other additional variables (inflation, industrial production, unemployment, two-tier system dummy) are low. The role of the two-tier system dummy is quite inconsistent. Its sign is positive in two countries, while in three countries it is negative. Overall, a conclusion similar to that of the corporate sector can be reached in the case of the household sector as well. In most of the countries, the extension of the error correction models did not improve the results. The previously existing relationship between households' cost of borrowing and the Euribor seems to be falling apart, when interest rates become negative.

Table 26: Results of the extended error correction models in the household sector in the second period

Country	Lag of cost of borrowing	Euribor	Lag of Euribor	Error correction term	Exchange rate	Inflation	Industrial production	Unemployment	Two-tier system dummy	Adjusted R-squared	Obser-vations
Estonia			0.3701 (0.171)	-0.1081*** (0.008)	0.8820** (0.041)					0.0947	86
Finland		0.4657*** (0.000)		-0.0007 (0.980)					0.0173*** (0.002)	0.4907	79
France	0.1776** (0.032) 0.3135*** (0.000)	0.1692** (0.038)		-0.1133*** (0.000)	0.7733*** (0.000)	-0.0205** (0.010)	-0.0038*** (0.000)	0.0012*** (0.007)	-0.0183** (0.019)	0.6490	73
Germany	0.2761*** (0.009)		0.5293*** (0.000)	-0.0200 (0.365)		-0.0210*** (0.004)				0.3799	73
Italy	0.1871* (0.089)	0.7334*** (0.001)		0.0382 (0.345)					0.0504** (0.044)	0.2492	86
Slovakia			0.1610 (0.427)	-0.1733*** (0.000)				0.0012** (0.033)	-0.0468** (0.031)	0.2701	73
Slovenia			0.2887** (0.013)	-0.0505* (0.068)		-0.0269*** (0.002)	-0.0051*** (0.000)		-0.0325*** (0.001)	0.4083	73

Note: In the case of Austria, Cyprus, Greece, Luxembourg, Malta, the Netherlands the results correspond to the outcomes of the non-extended ECMs, so they are omitted from the table. In the case of Estonia the 12th lag of the 3-month Euribor and in Slovakia the 5th lag of the 12-month Euribor are shown in the table but they are not significant, so they are not included in *Table 25*.

Source: Estimation by the author based on ECB and Eurostat data

4.3. Vector autoregressive models

As *Table 4* and *Table 5* show cost of borrowing in some countries is not cointegrated with any maturities of the Euribor. In these cases, the transmission of negative interest rates is going to be studied by vector autoregressive (VAR) models.

A simple VAR model can be written as (Wooldridge, 2015):

$$y_t = \delta_0 + \alpha_1 y_{t-1} + \gamma_1 z_{t-1} + \alpha_2 y_{t-2} + \gamma_2 z_{t-2} + \ldots + \alpha_k y_{t-k} + \gamma_k z_{t-k} \tag{10}$$

$$z_t = \eta_0 + \beta_1 y_{t-1} + \rho_1 z_{t-1} + \beta_2 y_{t-2} + \rho_2 z_{t-2} + \ldots + \beta_k y_{t-k} + \rho_k z_{t-k} \tag{11}$$

The countries where vector autoregressive models will be used instead of error correction models are presented here by *Table 27* for clarity.

Table 27: Countries where cost of borrowing is not cointegrated with the Euribor

Corporate sector	Household sector
Greece, Italy, Latvia, Lithuania, Malta, Slovakia, Spain	Belgium, Ireland, Latvia, Lithuania, Portugal, Spain, Euro Area

Source: Estimated by the author based on ECB data

4.3.1. Vector autoregressive models with dummy variable

Similarly to the error correction models, I started the analysis with the necessary econometric tests. I established stationarity using the Dickey Fuller test. I found that the time series of corporate borrowing costs are stationary in Latvia, Lithuania and Malta. However, in order to get comparable results, each model is estimated in first differences. After this, I obtained the lag-order selection statistics for the VAR models. I used the Schwarz information criterion for large samples (above 100 observations) and the Akaike information criterion for small samples (below 100 observations). After running the VAR models, I tested for stability[10], autocorrelation[11] and Granger causality. When autocorrelation was found, I adjusted the number of lags included in the models, which solved the problem in all but one case. (In the case of Slovakia, a VAR model with a dummy variable could not be estimated due to autocorrelation up to five lags.)

---

[10] I checked the eigenvalue stability condition after estimating the parameters of the VAR models. Based on Hamilton (1994) and Lütkepohl (2005).

[11] I implemented the Lagrange Multiplier (LM) test to check for autocorrelation in the residuals. Based on Johansen (1995).

First, I included a dummy variable in the VAR models that takes the value of 1 when the Euribor is negative and 0 otherwise. *Table 28* provides a summary of the maturities of the Euribor that were used in the case of the VAR models of corporates’ cost of borrowing, the time frame of the analyses, the number of observations and the number of lags used. The models were run for the entire period from the first available data point to the last negative value of the Euribor.

Table 28: Maturities of Euribor, time frame of the analyses, the number of observations and the number of lags in the corporate sector

Maturities of Euribor		
3-month	**6-month**	**12-month**
Latvia, Spain	Malta, Slovakia	Greece, Italy, Lithuania
Countries	**Time frame of the analyses**	**Number of lags**
Greece	April 2003 – February 2022 (227)	2
Italy	May 2003 – February 2022 (226)	3
Latvia	June 2014 – June 2022 (97)	4
Lithuania	June 2015 – February 2022 (81)	4
Malta	April 2008 – May 2022 (170)	2
Spain	April 2003 – June 2022 (231)	2

Source: Constructed by the author based on ECB data

A dummy variable, $I_{xt < 0}$, is added to the VAR model, which takes the value of 1 when the Euribor is negative and 0 otherwise:

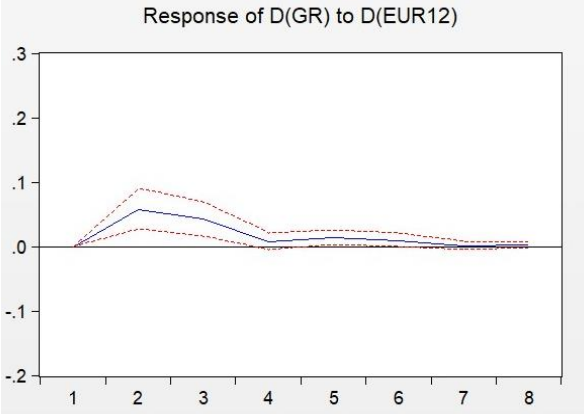
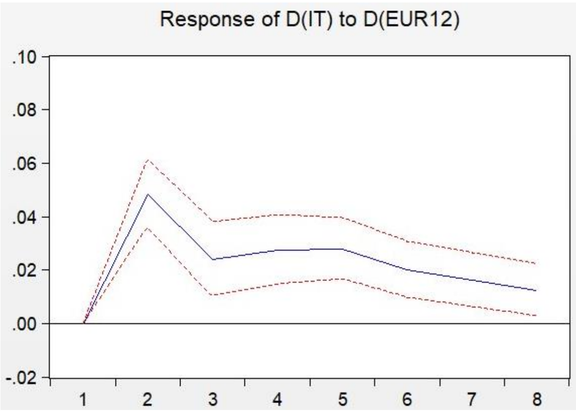
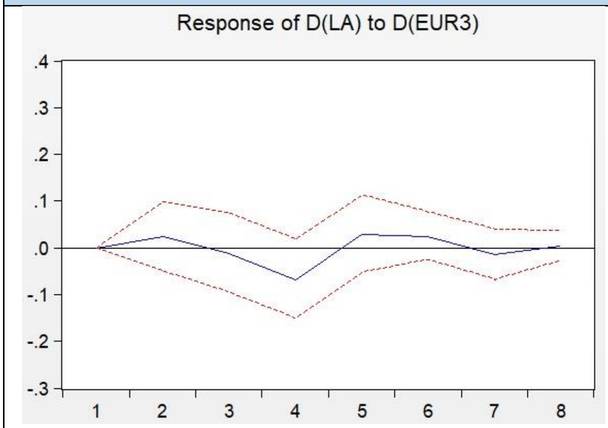
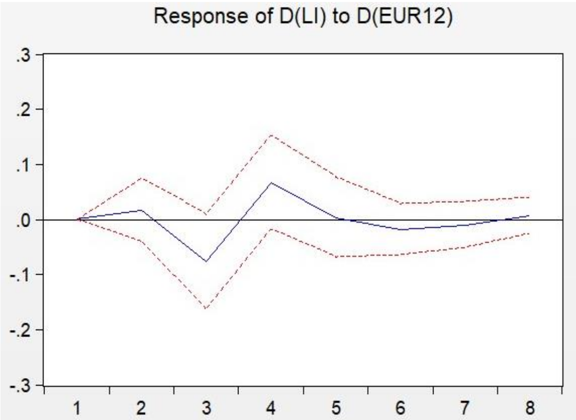
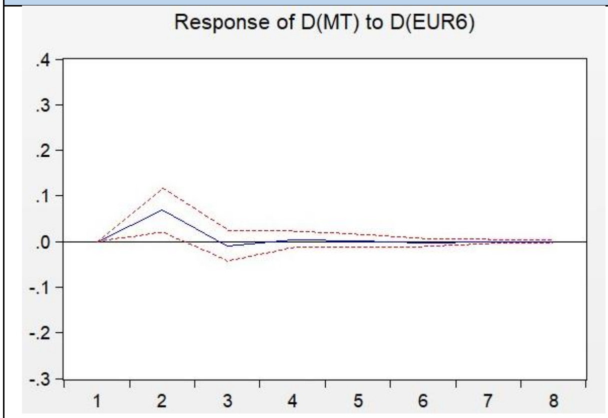
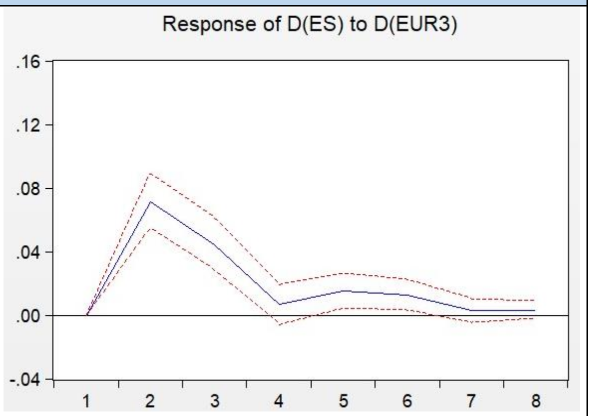
$$y_t = \delta_0 + \alpha_1 y_{t-1} + \gamma_1 z_{t-1} + \alpha_2 y_{t-2} + \gamma_2 z_{t-2} + \ldots + \alpha_k y_{t-k} + \gamma_k z_{t-k} + I_{xt < 0} \quad (12)$$

$$z_t = \eta_0 + \beta_1 y_{t-1} + \rho_1 z_{t-1} + \beta_2 y_{t-2} + \rho_2 z_{t-2} + \ldots + \beta_k y_{t-k} + \rho_k z_{t-k} + I_{xt < 0} \quad (13)$$

The adjusted R-squared varies between 31 percent and 48 percent across countries, which is rather low. This means that the models explain less than half of the variance in corporate borrowing costs. The dummy variable for negative interest rates turned out to be significant only in Greece at the level of 5 percent and in Spain at the level of 10 percent. The coefficient of the dummy variable is slightly negative in both cases. It is -0.067 in Greece and -0.027 in Spain, implying that the change in corporates' cost of borrowing is smaller when the Euribor is negative. These results again suggest that negative interest rates hinder the transmission mechanism of monetary policy through the interest rate channel and have different effects across Euro Area member states.

Figure 14 depicts the impulse response functions (IRFs) of corporates' cost of borrowing. The results show a moderate positive response in the case of Greece, Italy, Malta and Spain, while the effects are mixed in the case of Latvia and Lithuania. In most of the countries, the impact of the shock is fading away rather quickly. The VAR models suggest that interest rate transmission through the interest rate channel was operating in Greece, Italy, Malta and Spain during the period under review. In spite of the fact that corporates' cost of borrowing in these countries is not cointegrated with the Euribor.

Figure 14: Impulse response functions of corporates' cost of borrowing – Dummy variable models

Greece	**Italy**
	
Latvia	**Lithuania**
	
Malta	**Spain**
	

Notes: The variables are coded as follows: EUR3 = 3-month Euribor, EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, GR = Greece, IT = Italy, LA = Latvia, LI = Lithuania, MT = Malta and ES = Spain. 'D' refers to the first difference of the variable. Response to Cholesky one S.D. innovations +/- 2 S.E.

Source: Estimation by the author based on ECB data

The variance decomposition tables are available in the Appendix (*Table 35*). They show that in the case of Greece, Latvia, Lithuania and Malta, most of the variance is explained by own-lagged values of corporate borrowing costs, while in Italy and Spain the Euribor plays an important role. According to the Granger causality test, the Euribor Granger causes corporates' cost of borrowing in Greece, Italy and Spain at the 1 percent level, and in Malta at the 5 percent level. No Granger causality has been found for Latvia and Lithuania. The next section provides a more detailed analysis by dividing the sample into positive and negative interest rate environments.

Table 29 provides a summary of the maturities of the Euribor that were used in the case of the VAR models of households' cost of borrowing, the time frame of the analyses, the number of observations and the number of lags used. The models were run for the entire period from the first available data point to the last negative value of the Euribor.

Table 29: Maturities of Euribor, time frame of the analyses, the number of observations and the number of lags in the household sector

Maturities of Euribor	
6-month	**12-month**
Latvia, Portugal	Belgium, Ireland, Lithuania, Spain, Euro Area

Country	**Time frame of the analyses (Number of observations)**	**Number of lags**
Belgium	March 2003 – February 2022 (228)	1
Ireland	June 2003 – February 2022 (225)	4
Latvia	May 2014 – May 2022 (97)	3
Lithuania	April 2015 – February (2022) (83)	2
Portugal	June 2003 – May 2022 (228)	4
Spain	May 2003 – February 2022 (226)	3
Euro Area	March 2003 – February 2022 (228)	1

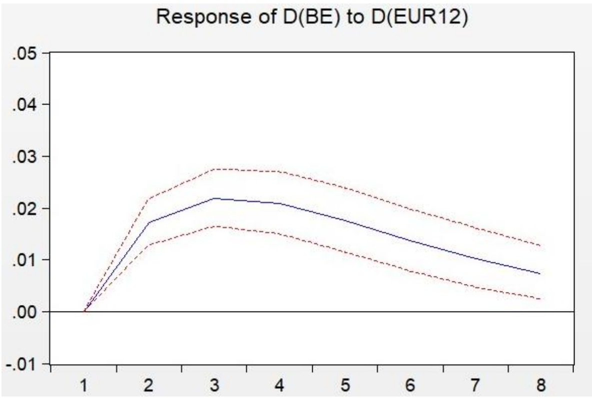
Source: Constructed by the author based on ECB data

The adjusted R-squared in the VAR models for the household sector is usually considerably higher than for the corporate sector. It is above 70 percent in Portugal, Spain and the Euro Area. This means that more than two-thirds of the variance is explained by Euribor and own-lagged values of household borrowing costs. Lithuania is again an exception with less than 2 percent.

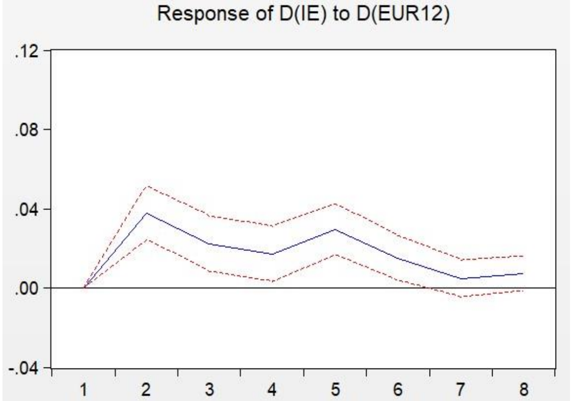
In contrast to the corporate sector, the negative interest rate dummy variable in the household sector is not significant in any country. These results may be an indication that negative interest rates do not have an impact on the cost of borrowing for households in the countries under review. However, I do not want to draw premature conclusions; a more thorough analysis is needed, which will be done in the following section. The impulse response functions in *Figure 15* show a positive reaction to a shock in the Euribor in most cases. However, similar to the corporate sector, the response is mixed in Latvia and Lithuania. Again, the two-period VAR models in the next section will provide more information on the impact of negative interest rates on households' cost of borrowing.

Figure 15: Impulse response functions of households' cost of borrowing – Dummy variable models

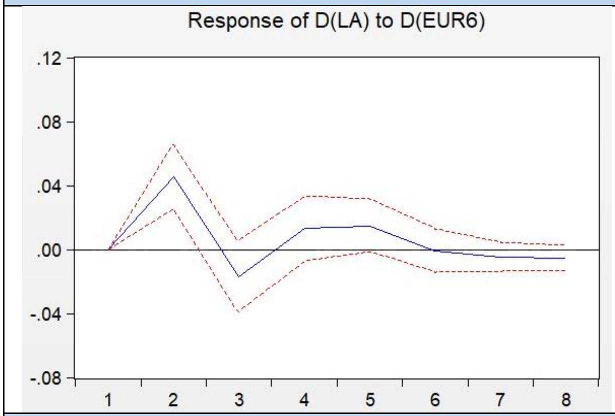
Belgium



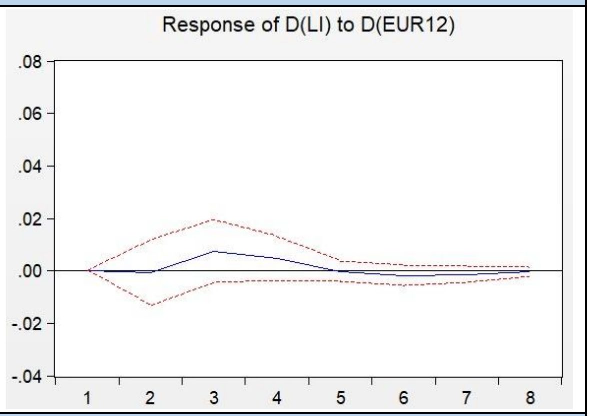
Ireland



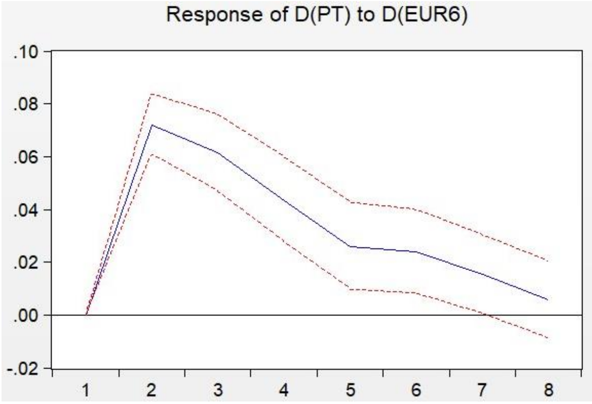
Latvia



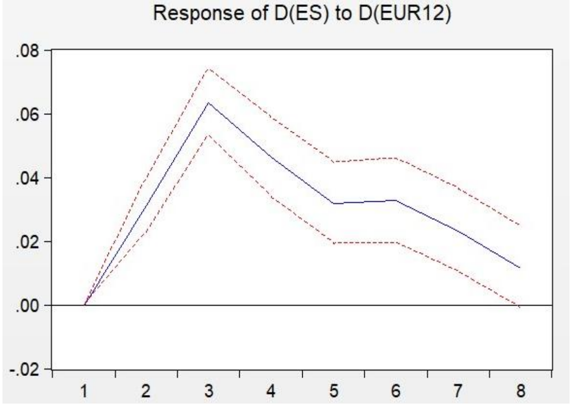
Lithuania

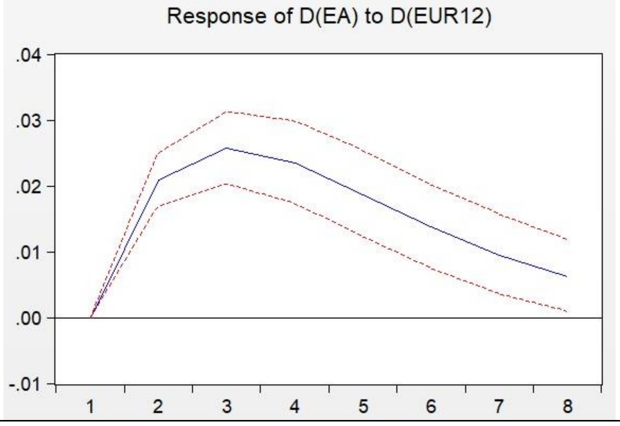


Portugal



Spain



Euro Area


Notes: The variables are coded as follows: EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, BE = Belgium, IE = Ireland, LA = Latvia, LI = Lithuania, PT = Portugal, ES = Spain and EA = Euro Area. 'D' refers to the first difference of the variable. Response to Cholesky one S.D. innovations +/- 2 S.E.
Source: Estimation by the author based on ECB data

The variance decomposition tables (Appendix, *Table 36*) also show that the Euribor has a strong effect on household borrowing costs in Portugal, Spain and the euro area, a moderate effect in Belgium, Ireland and Latvia and a weak effect in Lithuania. Granger causality has been found at the 1 percent level in all countries with the exception of Lithuania.

4.3.2. Two-period vector autoregressive models

In this section, similar to the error correction models, I have divided the sample into two periods: in the first, the Euribor is positive, while in the second, it is negative. *Table 30* summarizes the time frame of the analyses and the number of observations and lags used in the models. The Euribor maturities are the same as in the dummy variable models. (In the case of Latvia and Lithuania, the number of observations in the first period is insufficient, so these two countries are excluded from this part of the analysis.)

Table 30: Time frame of the analyses, the number of observations and the number of lags in the corporate sector

Country	**Time frame of the analyses – 1st period (Number of observations)**	**Time frame of the analyses – 2nd period (Number of observations)**	**Number of lags**
Greece	April 2003 – January 2016 (154)	February 2016 – February 2022 (73)	2
Italy	May 2003 – January 2016 (153)	February 2016 – February 2022 (73)	3, 2
Malta	April 2008 – October 2015 (91)	November 2015 – May 2022 (79)	2
Slovakia	June 2008 – October 2015 (89)	November 2015 – May 2022 (79)	4
Spain	April 2003 – April 2015 (145)	May 2015 – June 2022 (86)	2, 3

Notes: The lag structure may change between the two periods due to significance and/or autocorrelation issues. The second number in the number of lags column refers to the lags used in the second period.
Source: Constructed by the author based on ECB data

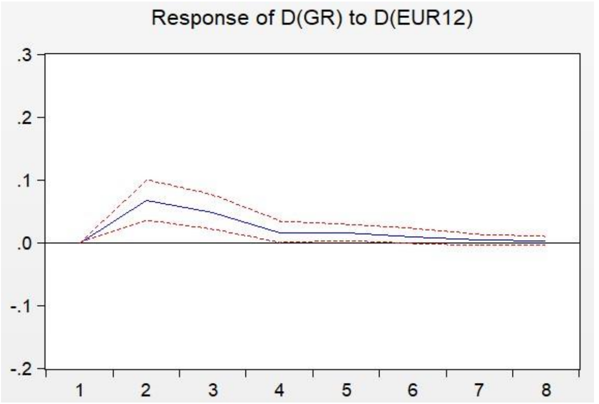
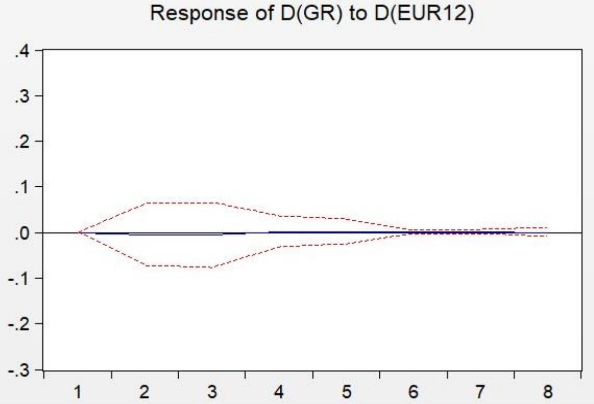
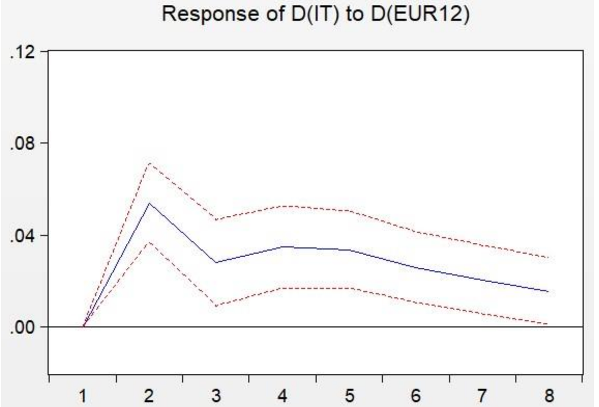
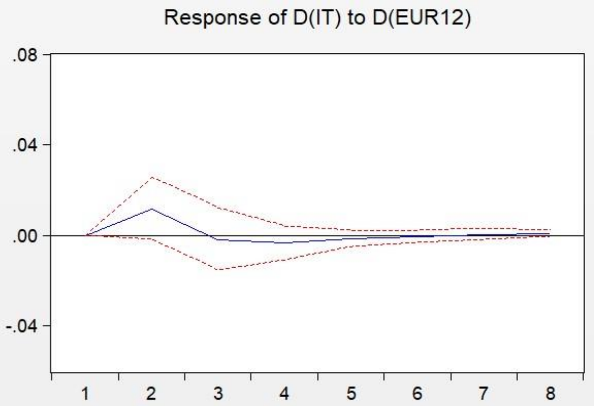
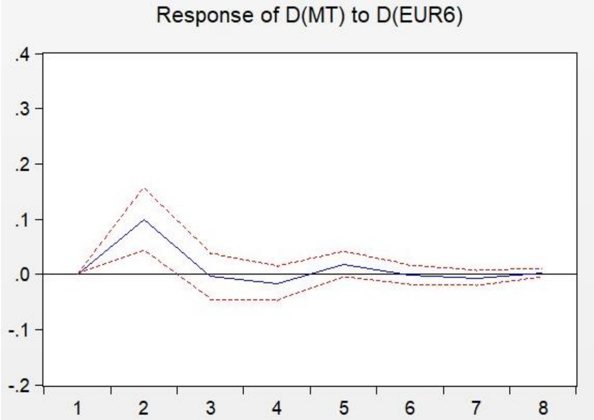
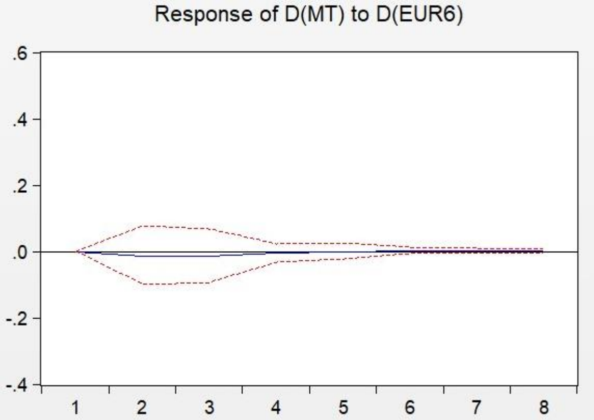
In this section, the estimated equations correspond to the simple VAR model (*Equation 10 and Equation 11*).

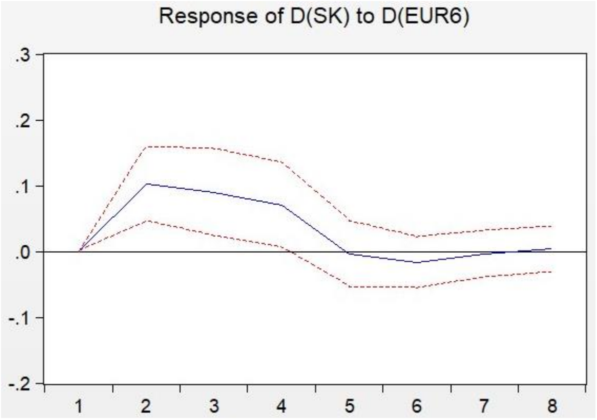
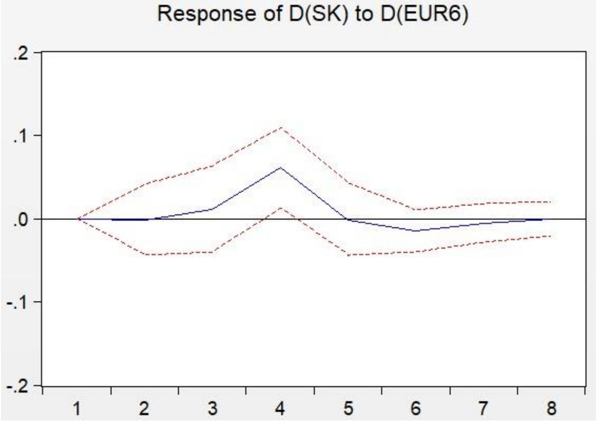
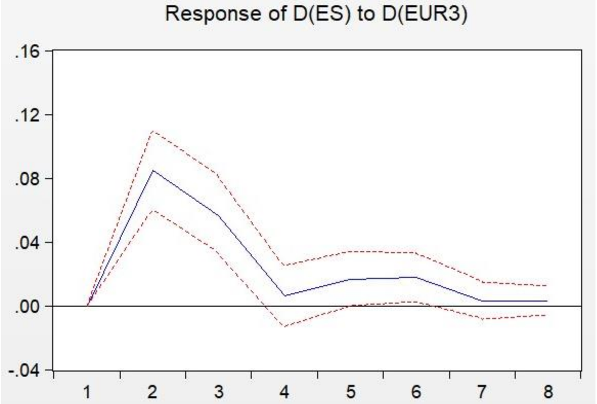
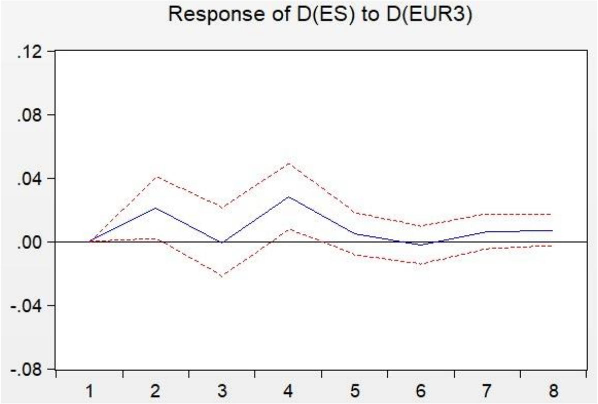
In a positive interest rate environment, adjusted R squared varies between 25 and 46 percent across countries in the corporate sector, which is again rather low. When the Euribor turns negative, the explanatory power of the models falls in all countries except Greece, where it rises. The decline is generally moderate, except for Italy, where it is almost 30 percent.

The impulse response functions are shown in *Figure 16*. The graphs in the left-hand column illustrate the first period when the Euribor was positive, while the graphs in the right-hand column show the second period when the Euribor was negative. It can be seen that, in the first period, corporates' cost of borrowing reacts positively to a shock in the Euribor in every country. The graphs show a moderate response, which is not surprising given that the VAR models were estimated in first differences to obtain stationarity and the shock is one standard deviation. Similar to the error correction models, the VAR models also point to a working interest rate channel of monetary transmission in the countries under review in the first period when the Euribor was positive.

In the period of negative interest rates, corporates' cost of borrowing in Greece and Malta is essentially unresponsive to a shock in the Euribor. In Italy and Spain, the response is smaller and runs out earlier than in the first period. Finally, in Slovakia the magnitude is also smaller and the response occurs later. Again, the results are similar to those of the error correction models, with transmission through the interest rate channel weakening in a negative interest rate environment. (The results also suggest that the higher explanatory power of the model for Greece in the second period is not due to the Euribor.)

Figure 16: Impulse response functions of corporates' cost of borrowing – Two-period models

1^{st} period: Positive interest rates	2^{nd} period: Negative interest rates
Greece	**Greece**
	
Italy	**Italy**
	
Malta	**Malta**
	

Slovakia	**Slovakia**
	
Spain	**Spain**
	

Notes: The variables are coded as follows EUR3 = 3-month Euribor, EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, GR = Greece, IT = Italy, LA = Latvia, LI = Lithuania, MT = Malta SK = Slovakia and ES = Spain. ‘D’ refers to the first difference of the variable. Response to Cholesky one S.D. innovations +/- 2 S.E.

Source: Estimation by the author based on ECB data

According to the variance decomposition tables (Appendix, *Table 37*), the trends are similar to those observed for the dummy models. The Euribor also plays a more important role in Italy, Spain and Slovakia than in the other countries in the first period. However, in a negative interest rate environment, the variance explained by the Euribor falls drastically in all countries. In the first period, Granger causality was established at the 1 percent level in all countries. In the second period, however, it was lost for Greece, Italy and Malta. The fact that the Euribor no longer Granger-causes corporates' borrowing costs in the negative interest rate period is also an indication of the weakening of the transmission mechanism.

The time frame of analyses, number of observations and lags used in the two-period VAR models for household borrowing costs are shown in *Table 31*.

Table 31: Time frame of the analyses, the number of observations and the number of lags in the household sector

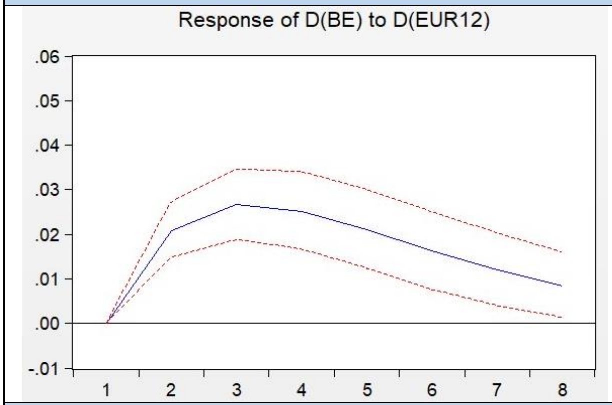
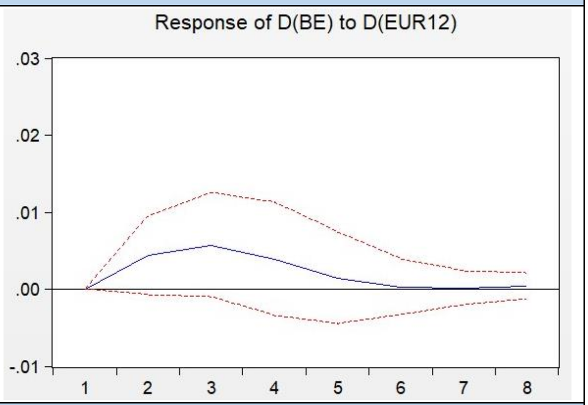
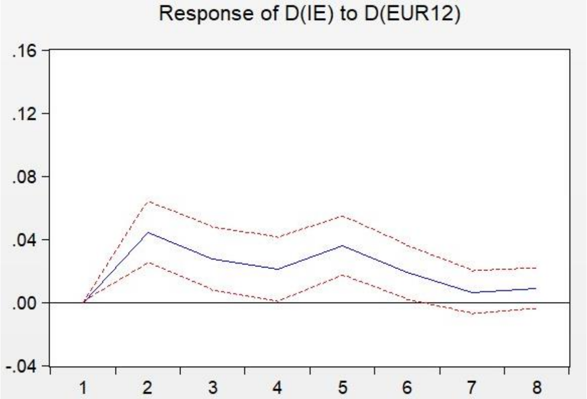
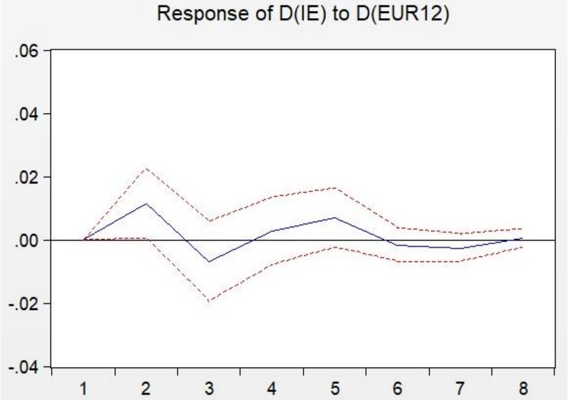
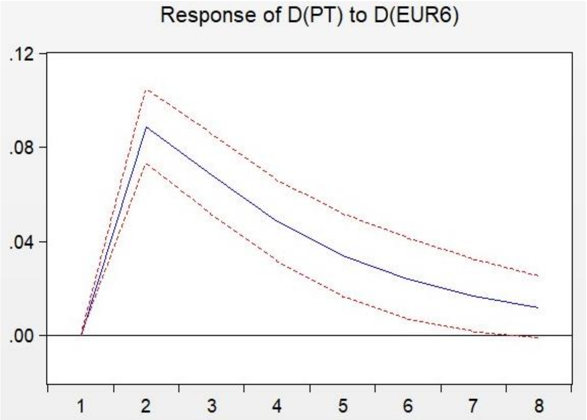
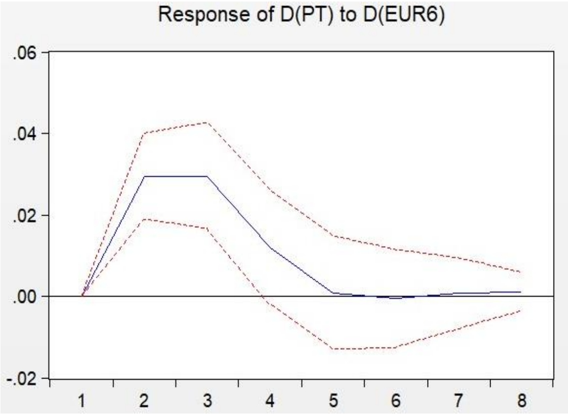
Country	**Time frame of the analyses – 1st period (Number of observations)**	**Time frame of the analyses – 2nd period (Number of observations)**	**Number of lags**
Belgium	March 2003 – January 2016 (155)	February 2016 – February 2022 (73)	1, 2
Ireland	June 2003 – January 2016 (152)	February 2016 – February 2022 (73)	4, 3
Portugal	March 2003 – October 2015 (152)	November 2015 – May 2022 (79)	1, 2
Spain	May 2003 – January 2016 (153)	February 2016 – February 2022 (73)	3, 2
Euro Area	March 2003 – January 2016 (155)	February 2016 – February 2022 (73)	1, 4

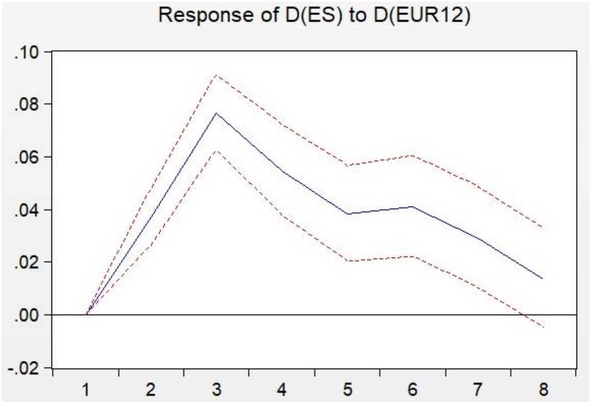
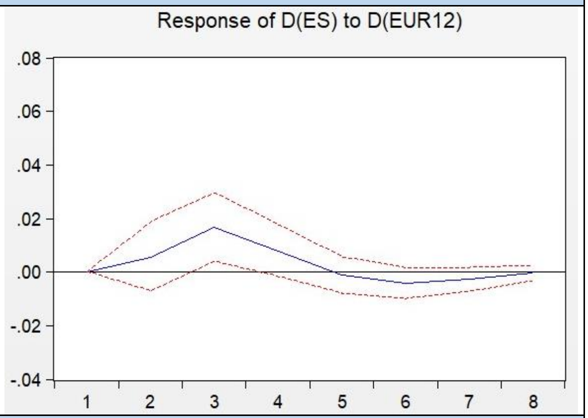
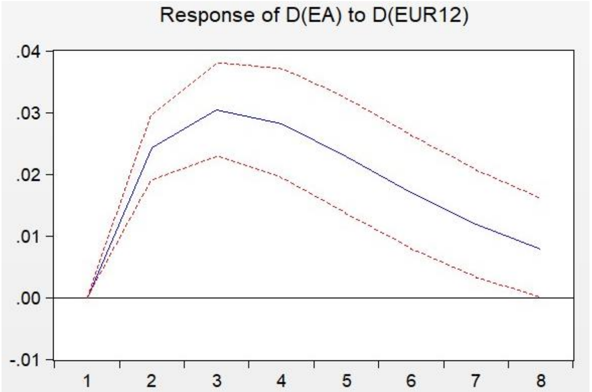
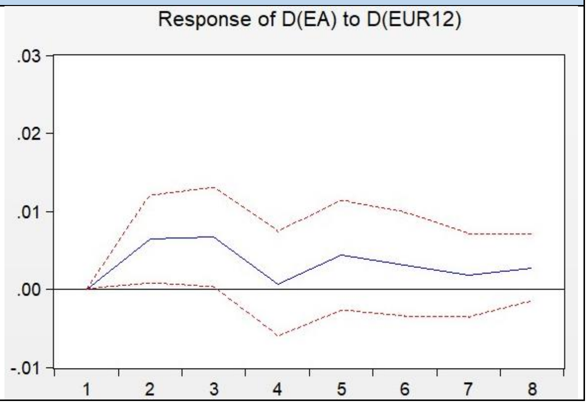
Notes: The lag structure may change between the two periods due to significance and/or autocorrelation issues. The second number in the number of lags column refers to the lags used in the second period.
Source: Constructed by the author based on ECB data

In the positive interest rate period, adjusted R squared is quite high in all countries except Ireland. The value of the indicator is around 80 percent in Spain and the Euro Area and also above 70 percent in Portugal. This means that most of the variance in household borrowing costs is explained by the models. However, when Euribor turns negative, adjusted R squared falls dramatically in all countries except Ireland (where it was not high in the first period).

Figure 17 presents the impulse response functions. In the first period, a positive response and a gradual descend can be observed in Belgium, Portugal, Spain and the Euro Area. However, the impact is smaller and fades away more quickly in the second period, when the Euribor was negative. These results also support previous findings on the weakening of interest rate transmission when interest rates are negative.

Figure 17: Impulse response functions of households' cost of borrowing – Two-period models

1st period: Positive interest rates	**2nd period: Negative interest rates**
Belgium	**Belgium**
	
Ireland	**Ireland**
	
Portugal	**Portugal**
	

Spain	**Spain**
	
Euro Area	**Euro Area**
	

Notes: The variables are coded as follows EUR3 = 3-month Euribor, EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, BE = Belgium, IE = Ireland, LA = Latvia, LI = Lithuania, PT = Portugal, ES = Spain and EA = Euro Area. ‘D’ refers to the first difference of the variable. Response to Cholesky one S.D. innovations +/- 2 S.E.
Source: Estimation by the author based on ECB data

According to the variance decomposition tables (Appendix, *Table 38*), in some countries (Portugal, Spain and the Euro Area) the Euribor explained most or a large part of the variance in households' cost of borrowing in the first period. However, this declined drastically in the negative interest rate environment. Granger causality was found for all countries in both periods, with the exception of Belgium, where it was lost when the Euribor turned negative. This is an interesting result, as the impulse response functions show a weakening, but the Euribor still Granger causes households’ borrowing costs in most countries in the second period.

Similar to the extended error correction models, typically only one or no additional variables remained significant in the vector autoregressive models, and autocorrelation was also a problem. Therefore, the extended VAR models are not included in the dissertation.

4.4. Results

My doctoral research focuses on the interest rate channel of the monetary transmission mechanism. I study how this channel operates in Euro Area countries when nominal interest rates become negative. I have formulated the following three research questions and hypotheses for my dissertation:

Research question 1: How does monetary transmission through the interest rate channel change in Euro Area countries if the policy rate becomes negative?

- **Hypothesis 1:** Monetary transmission through the interest rate channel weakens in Euro Area countries if the policy rate becomes negative.

Research question 2: Does negative interest rate policy have similar effects on the interest rate transmission across Euro Area countries?

- **Hypothesis 2:** The negative interest rate policy has different effects on the interest rate transmission in Euro Area countries.

Research question 3: How does the negative interest rate policy affect monetary transmission through the interest rate channel in the corporate and in the household sectors?

- **Hypothesis 3:** The monetary transmission mechanism is less effective in the household sector than in the corporate sector when the policy rate is negative.

I followed a joint approach, the results of the error correction and the vector autoregressive models have to be interpreted together, as the use of both types of models was necessary due to the lack of cointegration with the Euribor in some countries. The models are suitable for testing all three hypotheses and the two-period models have made the results of the dummy variable models more robust.

In the corporate sector, the dependent variable, the cost of borrowing, is cointegrated with the independent variable, the Euribor, in twelve countries and the Euro Area. In the error correction models, the dummy variable, the interaction term or both proved to be significant in eight countries and in the Euro Area. In the household sector, cointegration was found for thirteen countries. In eight member states, the dummy variable, the interaction term or both were significant in the error correction models. In the corporate sector, the coefficients of the dummy variable and the interaction term are negative in all countries where they are significant. In the household sector, the coefficients are negative in six out of eight countries.

In the next part of the research, I divided the time frame of the analysis into two periods. In the first period the Euribor was positive, while in the second one it was negative. The error correction models confirm the relationship between corporates' cost of borrowing and the Euribor in the first period. The dependent variable adjusts to its equilibrium value in every country and in the Euro Area, although considerable differences can be observed regarding the speed of this adjustment. In nine out of twelve countries, the previously existing relationship falls apart when the Euribor is negative. In the second period, the Euribor also becomes insignificant in the case of the Eurozone. In the household sector, the results are similar. In eleven out of thirteen member states, the relationship between households' cost of borrowing and the Euribor collapses in the second period, when the Euribor is negative. I extended the error correction models with several additional variables that may capture the macroeconomic environment. However, the results proved to be quite similar to the outcomes of the non-extended models.

In the VAR models, the dummy variable for negative interest rates was significant in two countries for the corporate sector, while it was insignificant in all cases for the household sector. The two-period models provided more information on interest rate transmission in those countries where no cointegration was found. Although there are differences in the magnitude and duration of the shock, in the first period, cost of borrowing responds positively to a change in the Euribor in both the corporate and household sectors. In the corporate sector, in two out of five countries, cost of borrowing stops responding to changes in the Euribor when interest rates become negative. In the other three countries, the response is smaller and disappears more quickly. In the household sector, the magnitude of the shock is also smaller in the second period and the duration becomes shorter as well.

After reviewing the results, the research questions can now be answered:

Research question 1: How does monetary transmission through the interest rate channel change in Euro Area countries if the policy rate becomes negative?

- **Hypothesis 1:** Monetary transmission through the interest rate channel weakens in Euro Area countries if the policy rate becomes negative.

Based on the ECM and the VAR models, I can confirm the first hypothesis. Monetary transmission through the interest rate channel weakens in most Euro Area countries if the policy rate becomes negative. The error correction model with dummy variable and interaction term already suggested the weakening of transmission (they are negative in the majority of cases), and the two-period ECM and VAR models made it clear that in most countries transmission through the interest rate channel weakens or even collapses when the Euribor turns negative.

The second research question and hypothesis focused on the differences across the Eurozone member states.

Research question 2: Does negative interest rate policy have similar effects on the interest rate transmission across Euro Area countries?

- **Hypothesis 2:** The negative interest rate policy has different effects on the interest rate transmission in Euro Area countries.

When I formulated this research question and hypothesis, I did not expect that the speed of adjustment or the size and duration of a shock would be the same or quite similar across Euro Area countries. I was only interested in the direction of the relationship. In other words, if interest rate transmission is weakening, is it weakening in all countries or not? In a monetary union, it is reasonable to expect that member countries will converge over time.

According to my research, considerable differences exist across the Eurozone. In most countries, the transmission mechanism through the interest rate channel weakens when the Euribor turns negative. However, in some cases I have found no change or a positive impact. So, I can also confirm the second hypothesis. The negative interest rate policy has different effects on the interest rate transmission in Euro Area countries. The confirmation of this hypothesis is supported by both types of error correction models in the corporate and household sectors, and by both types of vector autoregressive models in the corporate sector. (The VAR models in the household sector gave rather similar results across countries).

A comprehensive and detailed analysis of heterogeneity across Euro Area member states is beyond the scope of this dissertation. What can be stated, based on the visual interpretation of the cost of borrowing indicators, is that the range (between the member states with the lowest and the highest borrowing costs) in the corporate sector has widened somewhat compared to the early 2000s. In the household sector, however, the range is basically the same. Heterogeneity within the Euro Area is certainly an interesting research topic. Analyzing bank-level data, Altavilla et al. (2020) find a reduction in heterogeneity due to unconventional monetary policy instruments. Meanwhile, looking at macroeconomic data, Coudert et al.

(2020) conclude that Euro Area members have not structurally converged. So the direction of progress is not clear.

The third research question and the third hypothesis were formulated along the lines of sectoral differences:

Research question 3: How does the negative interest rate policy affect monetary transmission through the interest rate channel in the corporate and in the household sectors?

- **Hypothesis 3:** The monetary transmission mechanism is less effective in the household sector than in the corporate sector when the policy rate is negative.

Based on the results of both types of error correction and vector autoregressive models, the third hypothesis can also be confirmed. In the ECM models, the adjustment to the equilibrium value is faster in the corporate sector, implying that interest rate transmission is more effective. In the VAR models, the response of the cost of borrowing in the corporate sector tends to be somewhat larger than in the household sector.

V. Conclusion

In July 2022 the European Central Bank ended the negative interest rate policy in order to curb down rising inflation in the monetary union. This provides a great opportunity to evaluate the performance of NIRP. It is crucial to understand what kind of results can be expected from the previously untested tool of central banks. I aim to contribute to this discussion with my work.

The first two parts of the literature review presented the main theories of money and interest rates and showed how the monetary transmission mechanism operates through the various channels. The evolution of economic thinking is quite interesting, how we go from the starting point of the classical view that money is neutral, so it cannot affect the real economy, to the crucial role that central banks now play in an economy. This evolution in economic thinking can also be seen in the emergence of new ways in which monetary policy can influence different areas of the economy.

The monetary policy toolkit has changed considerably over the past two decades, especially in the aftermath of the global financial crisis. Unconventional measures have become increasingly important, but traditional interest rate setting still plays an essential role in the transmission mechanism.

The third part of the literature review analyzed the issue of negative nominal interest rates from a theoretical and empirical point of view, while the fourth part focused on the Euro Area. Several important theoretical aspects of negative interest rates were touched upon, such as the role of cash or the reversal interest rates. The empirical literature on negative interest rates is rather contradictory, so further research is certainly needed. My view on this is that in the era of negative interest rates, some problems arose, which were addressed and the exit was possible without major negative consequences.

The theory of integration is an area of economics that has been extensively studied. The specific characteristics of the Eurozone raise interesting questions for monetary policy and pose challenges for decision-makers. Identifying the causes of the strong heterogeneity within the monetary union is beyond the scope of this dissertation, but it is a crucial issue that needs to be addressed, and not only for theoretical reasons. The 2020s have so far brought major challenges and the future is uncertain. Geopolitics is becoming more and more important and the EU needs to be prepared for different scenarios.

My research focused mainly on the effectiveness of the interest rate channel in Euro Area countries in a negative interest rate environment. Furthermore, I also identified differences in pass-through across member states and sectors. I used quantitative methods for the transmission analysis, estimating several types of error correction and vector autoregressive models that are often used in monetary economics. In an ECM, it is possible to determine the speed of pass-through, while the impulse response functions in a VAR model show the impact of a shock on a variable of interest. For the analysis, I used the Euribor as a proxy for policy interest rate and borrowing cost indicators in the corporate and household sectors. All data are publicly available in the databases of the European Central Bank and the European Commission (Eurostat).

The results of the estimated error correction and vector autoregressive models show that, in most Euro Area countries monetary transmission through the interest rate channel weakens or even collapses, when the policy interest rate becomes negative. There are considerable differences across the member states and the transmission mechanism is less effective in the household sector, than in the corporate sector.

As I mentioned earlier, the empirical literature on negative interest rates is quite controversial, so my findings are consistent with some papers but contradict others. For example, Eggertsson et al. (2017) and Kutasi & Szabó (2019) also conclude that the transmission mechanism breaks down when interest rates become negative. Fatum et al. (2019) find a weaker or nonexistent effect of macroeconomic news surprises on bond yields, while Heider et al. (2019) conclude that NIRP was not accommodative and posed a risk to financial stability.

At the same time, the results of Claeys (2021) show no difference in the impact of interest rate cuts in positive and negative interest rate environments. Meanwhile, Altavilla et al. (2019) find evidence of an even stronger transmission at negative interest rates.

So the controversy remains. What can be said is that the results on the effectiveness of monetary transmission depend to a large extent on which area of the pass-through is studied, and with what kind of data and models.

The novelty of my research lies in the fact that it focuses narrowly on the first step of the monetary transmission mechanism through the interest rate channel, i.e. the pass through of policy rate changes to commercial bank interest rates. In the literature, the most common approach is either the construction of a macro model or the use of bank or loan-level data, i.e.

micro-level data. It can be said that my research is somewhere in the middle, it looks at countries but the focus is narrow in terms of process. A further added value is the extension of the analysis to all Eurozone member states. Previous work has either looked at the Euro Area as a whole or at some of the larger member states, such as Germany or Italy.

The main conclusion that can be drawn from my research is that in most Euro Area countries we should not expect a well-functioning interest rate channel in a negative interest rate environment. If NIRP remains part of the monetary policy toolkit, it will have to rely on its effects through other channels. In addition, steps should be taken in order to reduce the high degree of heterogeneity within the Euro Area.

Naturally, my research has limitations. The focus was narrowed down to Euro Area countries and to the interest rate channel of the monetary transmission mechanism. The analysis does not touch upon the transmission of negative interest rates through other channels (e.g. asset prices, exchange rate, expectations), therefore it cannot provide a comprehensive study of the whole transmission mechanism. The inclusion of several macroeconomic indicators in the error correction models did not really give additional information about interest rate transmission and did not alter the results. Explanations for the outcomes may be provided by examining the institutional environment and the characteristics of the financial sector. The role of banks and banking sector features is actually a heavily researched area. It is also important to highlight that my research is not suitable to assess the performance of the euro, as a single currency or the issues within the Euro Area. A vast amount of literature is available regarding this topic. In relation to this area, my only goal here was to establish the existence of differences.

I have several ideas for future research. The error correction and vector autoregressive models used could be extended to include financial variables. The additional macro indicators I added to the error correction models did not provide much additional information, but the financial sector is likely to play an important role in the transmission. Other channels of the monetary transmission mechanism could also be taken into account. For example, the role of asset prices or expectations seems to be an interesting direction.

Although the era of negative interest rates is over for the time being, I believe that further research in this area is essential because, on one hand, ultra-loose monetary policy may be necessary in the future. On the other hand, it is also worth investigating how the monetary transmission looks like after negative interest rates.

References

Akram, T. (2016). *Japan's liquidity trap*. (Working Paper No. 862). Levy Economics Institute. https://www.levyinstitute.org/pubs/wp_862.pdf

Altavilla, C., Burlon, L., Giannetti, M., & Holton, S. (2019). *Is there a zero lower bound? The effects of negative policy rates on banks and firms*. (ECB Working Paper No. 2289). European Central Bank. https://data.europa.eu/doi/10.2866/23378

Altavilla, C., Canova, F., & Ciccarelli, M. (2020). Mending the broken link: Heterogeneous bank lending rates and monetary policy pass-through. *Journal of Monetary Economics*, *110*, 81-98. https://doi.org/10.1016/j.jmoneco.2019.01.001

Altissimo, F., Georgiou, E., Sastre, T., Valderrama, M. T., Sterne, G., Stocker, M., Weth, M., Whelan, K.,& Willman, A. (2005). *Wealth and asset price effects on economic activity*. (ECB Occasional Paper Series No. 29). European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpops/ecbocp29.pdf

Amato, J. D. (2005). The role of the natural rate of interest in monetary policy. *CESifo Economic Studies*, *51*(4), 729-755. https://doi.org/10.1093/cesifo/51.4.729

Amzallag, A., Calza, A., Georgarakos, D., & Sousa, J. (2019). *Monetary policy transmission to mortgages in a negative interest rate environment*. (ECB Working Paper No. 2243). European Central Bank. https://www.ecb.europa.eu//pub/pdf/scpwps/ecb.wp2243~a1f298ab9d.en.pdf

Andries, A. M., Cocriş, V., &Pleşcău, I. (2015). Low interest rates and bank risk-taking: Has the crisis changed anything? Evidence from the Eurozone. *Review of Economic and Business Studies*, *8*(1), 125-148. https://doi.org/10.1515/rebs-2016-0019

Angeloni, I., Faia, E., &Duca, M. L. (2015). Monetary policy and risk taking. *Journal of Economic Dynamics and Control*, *52*, 285-307. https://doi.org/10.1016/j.jedc.2014.12.001

Angeloni, I., Kashyap, A. K., Mojon, B., &Terlizzese, D. (2003). *Monetary Transmission in the Euro Area: Does the Interest Rate Channel Explain it All?* (NBER Working Paper Series No. 9984). National Bureau of Economic Research. https://www.nber.org/system/files/working_papers/w9984/w9984.pdf

Arestis, P. (2009). New Consensus macroeconomics and Keynesian critique. In E. Hein, T. Niechoj & E. Stockhammer (Ed.). *Macroeconomic policies on shaky foundations–Whither mainstream economics?* (pp. 165-187). Metropolis

Arestis, P., & Sawyer, M. (2008). A critical reconsideration of the foundations of monetary policy in the new consensus macroeconomics framework. *Cambridge Journal of Economics, 32*(5), 761-779. https://doi.org/10.1093/cje/ben004

Arias, M. A., & Wen, Y. (2014). The Liquidity Trap: An Alternative Explanation for Today's Low Inflation. *The Regional Economist*, *22*(2), 10-11. https://www.stlouisfed.org/publications/regional-economist/april-2014/the-liquidity-trap-an-alternative-explanation-for-todays-low-inflation

Arnold, M. (2019, August 26). *German banks wade into negative rate debate*. Financial Times. https://www.ft.com/content/6a0be970-c6b5-11e9-a1f4-3669401ba76f, Accessed: 10. 12. 2022.

Arteta, C., Kose, M. A., Stocker, M., & Taskin, T. (2016). *Negative interest rate policies: Sources and implications*. (Policy Research Working Paper No. 7791). World Bank Group. https://documents1.worldbank.org/curated/en/235551470834953672/pdf/WPS7791.pdf

Ashworth, P., & Davis, E. P. (2001). *Some evidence on financial factors in the determination of aggregate business investment for the G7 countries*. (NIESR Discussion Papers No. 187). National Institute of Economic and Social Research. https://core.ac.uk/download/pdf/333596.pdf

Assarsson, B., Berg, C., & Jansson, P. (2004). Investment in Swedish manufacturing: Analysis and forecasts. *Empirical Economics*, *29*(2), 261-280. https://doi.org/10.1007/s00181-003-0165-5

Assenmacher, K., & Krogstrup, S. (2018). *Monetary policy with negative interest rates: Decoupling cash from electronic money.* (IMF Working Paper No. 18/191). International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2018/08/27/Monetary-Policy-with-Negative-Interest-Rates-Decoupling-Cash-from-Electronic-Money-46076

Backhouse, R. E., & Boianovsky, M. (2016). Secular stagnation: The history of a macroeconomic heresy. *The European Journal of the History of Economic Thought*, *23*(6), 946-970. https://doi.org/10.1080/09672567.2016.1192842

Balassa, B. (1961). *The Theory of Economic Integration*. London, Allen and Unwin

Balogh, A., Horváth, Zs., & Kollarik, A. (2017): A hagyományos monetáris politikai transzmisszió, (MNB Oktatási Füzetek 17). Magyar Nemzeti Bank https://www.mnb.hu/letoltes/mnb-oktatasi-fuzetek-17-szam-2017-szeptember-balogh-andras-horvath-zsofia-kollarik-andras-a-hagyomanyos-monetaris-politikai-transzmisszio-online.pdf

Barot, B., & Yang, Z. (2002). House prices and housing investment in Sweden and the UK: Econometric analysis for the period 1970–1998. *Review of Urban & Regional Development Studies*, *14*(2), 189-216. https://doi.org/10.1111/1467-940x.00054

Barth III, M. J., & Ramey, V. A. (2001). The cost channel of monetary transmission. In B. S. Bernanke, & K. Rogoff (Eds.), *NBER Macroeconomics Annual: 16* (pp. 199-240). MIT Press. https://www.nber.org/books-and-chapters/nber-macroeconomics-annual-2001-volume-16/cost-channel-monetary-transmission

Békési, L., Köber, C., Kucsera, H., Várnai, T., & Világi, B. (2016). *The macroeconomic forecasting model of the MNB* (MNB Working Papers No. 2016/4). Magyar Nemzeti Bank. https://www.mnb.hu/letoltes/mnb-wp-2016-4-final.pdf

Berg, L., & Berger, T. (2006). The Q theory and the Swedish housing market—an empirical test. *The Journal of Real Estate Finance and Economics*, *33*(4), 329-344. https://doi.org/10.1007/s11146-006-0336-1

Bergsten, C. F. (2012). Why the Euro will survive: Completing the continent's half-built house. *Foreign Affairs*, 16-22.

Bernanke, B. S., & Gertler, M. (1995). Inside the black box: the credit channel of monetary policy transmission. *Journal of Economic Perspectives*, *9*(4), 27-48. https://doi.org/10.1257/jep.9.4.27

Blanchard, O., Rhee, C., & Summers, L. (1993). The stock market, profit, and investment. *The Quarterly Journal of Economics*, *108*(1), 115-136. https://doi.org/10.2307/2118497

Bond, S., & Cummins, J. (2001). *Noisy share prices and the Q model of investment* (IFS Working Papers No. 01/22). The Institute for Fiscal Studies. https://ifs.org.uk/sites/default/files/output_url_files/wp0122.pdf

Borio, C., & Zhu, H. (2012). Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism?. *Journal of Financial Stability*, *8*(4), 236-251. https://doi.org/10.1016/j.jfs.2011.12.003

Boucinha, M., Burlon, L., & Kapp, D. (2020). Negative rates and the transmission of monetary policy. *Economic Bulletin Articles*, *3*. https://www.ecb.europa.eu/press/economic-bulletin/articles/2020/html/ecb.ebart202003_02~4768be84e7.en.html

Brunnermeier, M. K., & Koby, Y. (2017). *The reversal interest rate: An effective lower bound on monetary policy*. Unpublished paper, Princeton University. https://scholar.princeton.edu/sites/default/files/markus/files/16f_reversalrate.pdf

Brunnermeier, M. K., & Koby, Y. (2018). *The reversal interest rate* (NBER Working Paper Series No. 25406). National Bureau of Economic Research. https://doi.org/10.3386/w25406

Buiter, W. H. (2007). "Is Numérairology the Future of Monetary Economics? Unbundling Numéraire and Medium of Exchange through a Virtual Currency with a Shadow Exchange Rate," *Research Papers in Economics*. https://econpapers.repec.org/paper/nbrnberwo/12839.htm

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of monetary Economics*, *12*(3), 383-398. https://doi.org/10.1016/0304-3932(83)90060-0

Cecioni, M., Ferrero, G., & Secchi, A. (2019). Unconventional monetary policy in theory and in practice. In *Innovative Federal Reserve policies during the great financial crisis* (pp. 1-36).

Claeys, G. (2021). *What Are the Effects of the ECB's Negative Interest Rate Policy?*. Monetary Dialogue Papers. Publication for the committee on Economic and Monetary Affairs, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, 2021. https://www.europarl.europa.eu/cmsdata/235691/02.%20BRUEGEL_formatted.pdf

Cloyne, J., Ferreira, C., & Surico, P. (2020). Monetary policy when households have debt: new evidence on the transmission mechanism. *The Review of Economic Studies*, *87*(1), 102-129.

Coenen, G., & Wieland, V. (2003). The zero-interest-rate bound and the role of the exchange rate for monetary policy in Japan. *Journal of Monetary Economics*, *50*(5), 1071-1101. https://doi.org/10.1016/s0304-3932(03)00055-2

Corneille, O., D'Hondt, C., De Winne, R., Efendic, E., & Todorovic, A. (2021). What leads people to tolerate negative interest rates on their savings?. *Journal of Behavioral and Experimental Economics, 93*, 101714. https://doi.org/10.1016/j.socec.2021.101714

Coudert, V., Couharde, C., Grekou, C., & Mignon, V. (2020). Heterogeneity within the euro area: New insights into an old story. *Economic Modelling, 90*, 428-444. https://doi.org/10.1016/j.econmod.2019.11.028

Croce, E., & Khan, M. S. (2000). Monetary regimes and inflation targeting. *Finance and development, 37*(3), 48-51. https://www.imf.org/external/pubs/ft/fandd/2000/09/croce.htm

Csortos, O., Lehmann, K., & Szalai, Z. (2014). Az előretekintő iránymutatás elméleti megfontolásai és gyakorlati tapasztalatai. *MNB Szemle 2014*(07), 45-55. https://mnb.hu/letoltes/csortos-orsolya-lehmann-kristof-szalai-zoltan.pdf

Danmarks Nationalbank. (2015, February 5). *Interest rate reduction* [Press release]. http://www.nationalbanken.dk/en/pressroom/Documents/2015/02/DNN201521789.pdf, Accessed: 26. 04. 2020.

Davis, E. P. (2011). New international evidence on asset-price effects on investment, and a survey for consumption. *OECD Journal: Economic Studies, 2010*(1), 1-50. https://doi.org/10.1787/eco_studies-2010-5km33scv75kc

Davis, E. P., & Stone, M. R. (2004). Corporate financial structure and financial stability. *Journal of Financial Stability, 1*(1), 65-91. https://doi.org/10.1016/j.jfs.2004.06.003

De Fiore, F., & Tristani, O. (2019). *(Un) conventional Policy and the Effective Lower Bound* (CEPR Discussion Papers No. 13585). Centre for Economic Policy Research. https://cepr.org/publications/dp13585

ECB (2019, September 19). *ECB introduces two-tier system for remunerating excess liquidity holdings* [Press release]. https://www.ecb.europa.eu/press/pr/date/2019/html/ecb.pr190912_2~a0b47cd62a.en.html

Eggertsson, G. B., Juelsrud, R. E., Summers, L. H., & Wold, E. G. (2019). *Negative nominal interest rates and the bank lending channel* (NBER Working Paper No. 25416). National Bureau of Economic Research. https://www.nber.org/papers/w25416

Eggertsson, G. B., Juelsrud, R. E., & Wold, E. G. (2017). *Are negative nominal interest rates expansionary?* (NBER Working Paper No. 24039). National Bureau of Economic Research. https://www.nber.org/papers/w24039

Eijffinger, S., & Masciandaro, D. (2018). *Hawks and doves: Deeds and words – Economics and politics of monetary policymaking*. CEPR Press

Emerson, M., Gros, D., & Italianer, A. (1992). *One market, one money: An evaluation of the potential benefits and costs of forming an economic and monetary union*. Oxford University Press on Demand.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, *55*(2), 251-276. https://doi.org/10.2307/1913236

Fatum, R., Hara, N., & Yamamoto, Y. (2019). *Negative Interest Rate Policy and the Influence of Macroeconomic News on Yields*. (Globalization and Monetary Policy Institute Working Paper No. 354). Federal Reserve Bank of Dallas. https://doi.org/10.24149/gwp354

Feraboli, K., Häkkinen, H., & Gutiérrez, J. M. P. (2015). A new indicator for the cost of borrowing in the euro area. In Irving Fisher Committee (Eds.), *Indicators to support monetary and financial stability analysis: data sources and statistical methodologies*. *IFC Bulletin No 39* (pp. 1-11). Bank for International Settlements. https://www.bis.org/ifc/publ/ifcb39.pdf

Fiorentini, G., Galesi, A., Pérez-Quirós, G., & Iváñez, E. S. (2018). *The rise and fall of the natural interest rate*. (BDE Working Paper No. 1822). Banco de España. https://www.bde.es/f/webbde/SES/Secciones/Publicaciones/PublicacionesSeriadas/DocumentosTrabajo/18/Files/dt1822e.pdf

Fisher, I. (1911). *The Purchasing Power of Money*. New York: The Macmillan Co.

Fisher, I., & Cohrssen, H. R. (1933). *Stamp scrip*. New York: Adelphi.

Frankel, J. A., & Rose, A. K. (1998). The endogenity of the optimum currency area criteria. *The Economic Journal*, *108*(449), 1009-1025. https://doi.org/10.1111/1468-0297.00327

Friedman, M. (1987) Quantity Theory of Money. In J. Eatwell, M. Milgate, & P. Newman (Ed.). *The New Palgrave: A Dictionary of Economics*. Vol. 4. pp. 3-20, New York: Stockton Press, London: Macmillan.

Frömmel, T. (2017). The Rational Expectations Hypothesis: Theoretical Critique. *E-LOGOS– Electronic Journal for Philosophy, 24*(2), 4-12. https://doi.org/10.18267/j.e-logos.443

Galí, J. (2018). The state of new Keynesian economics: A partial assessment. *Journal of Economic Perspectives, 32*(3), 87-112. https://doi.org/10.1257/jep.32.3.87

Gatch, L. (2006). Local Scrip in the USA during the 1930s: Lessons for Today. In *Conference on Monetary Regionalisation: Local Currencies as Catalysts for Endogenous Regional Development* (pp. 28-29). Bauhaus-University Weimar. Germany. September. https://www.complementarycurrency.org/ccLibrary/Local_Scrip_in_the_USA-Gatch.pdf

George, E., King, M., Clementi, D., Budd, A., Buiter, W., Goodhart, C., Julius, D., Plenderleith, i., & Vickers, J. (1999). *The transmission mechanism of monetary policy*. Bank of England, Quarterly Bulletin. 161-170. https://www.bankofengland.co.uk/-/media/boe/files/quarterly-bulletin/1999/the-transmission-mechanism-of-monetary-policy

Gern, K. J., Jannsen, N., Kooths, S., & Wolters, M. (2015). Quantitative easing in the euro area: Transmission channels and risks. *Intereconomics, 50*(4), 206-212.

Gesell, S. (1891). *Die Reformation im Münzwesen als Brücke zum sozialen Staat*. Selbstverlag des Verfassers.

Gesell, S. (1958). *The natural economic order*. London: Owen.

Goodfriend, M. (2000). Overcoming the zero bound on interest rate policy. *Journal of Money, Credit and Banking, 32*(4), 1007-1035. https://doi.org/10.2307/2601157

Granger, C. W. (1981). Some properties of time series data and their use in econometric model specification. *Journal of Econometrics, 16*(1), 121-130. https://doi.org/10.1016/0304-4076(81)90079-8

Halmai, P. (2020). *Európai gazdasági integráció*. Ludovika Egyetemi Kiadó.

Hamilton, J. D. (1994). *Time Series Analysis*. Princeton, NJ: Princeton University Press.

Hamilton, J. D., Harris, E. S., Hatzius, J., & West, K. D. (2016). The equilibrium real funds rate: Past, present, and future. *IMF Economic Review, 64*(4), 660-707. https://doi.org/10.1057/s41308-016-0015-z

Hansen, A. H. (1939). Economic progress and declining population growth. *The American Economic Review, 29*(1), 1-15. https://www.jstor.org/stable/1806983

Heider, F., Saidi, F., & Schepens, G. (2019). Life below zero: Bank lending under negative policy rates. *The Review of Financial Studies, 32*(10), 3728-3761. https://doi.org/10.1093/rfs/hhz016

Hicks, J. R. (1937). Mr. Keynes and the" Classics"; A Suggested Interpretation. *Econometrica*, *5*(2) 147-159. https://doi.org/10.2307/1907242

Holm, M. B., Paul, P., & Tischbirek, A. (2021). The transmission of monetary policy under the microscope. *Journal of Political Economy*, *129*(10), 2861-2904.

Holston, K., Laubach, T., & Williams, J. C. (2017). Measuring the natural rate of interest: International trends and determinants. *Journal of International Economics*, *108*, S59-S75. https://doi.org/10.1016/j.jinteco.2017.01.004

Homburg, S. (2017). Understanding benign liquidity traps: The case of Japan. *German Economic Review, 18*(3), 267-282. https://doi.org/10.1111/geer.12105

Honda, Y. & Inoue, H. (2017). *The Effectiveness of the Negative Interest Rate Policy in Japan: An Early Assessment*. (Discussion Papers in Economics and Business 17-02). Osaka University, Graduate School of Economics. https://ideas.repec.org/p/osk/wpaper/1702.html

Humphrey, T. M. (1974). The Quantity Theory of Money: Its Historical Evolution and Role in Policy Debates. *Econometric Reviews, 60,* 2-19. https://EconPapers.repec.org/RePEc:fip:fedrer:y:1974:i:may:p:2-19:n:v.60no.3

Ilgmann, C., & Menner, M. (2011). Negative nominal interest rates: history and current proposals. *International Economics and Economic Policy*, *8*(4), 383-405. https://doi.org/10.1007/s10368-011-0186-z

IMF. (2022). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions* (Report No. 978-1-51359-846-8). International Monetary Fund. https://www.imf.org/en/Publications/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions/Issues/2022/07/19/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions-2021-465689

Ireland, P. N. (2010). Monetary transmission mechanism. In S. N. Durlauf, & L. E. Blume (Ed.). *Monetary Economics* pp. 216-223. London: Palgrave Macmillan.

Jahan, S., Mahmud, A. S., & Papageorgiou, C. (2014). What is Keynesian economics?. *International Monetary Fund, 51*(3), https://www.imf.org/external/pubs/ft/fandd/2014/09/basics.htm

Jahan, S., & Papageorgiou, C. (2014). What is monetarism. *Finance & Development, 51*(1), https://www.imf.org/external/pubs/ft/fandd/2014/03/basics.htm

Jašová, M., Moessner, R., & Takáts, E. (2016). *Exchange rate pass-through: What has changed since the crisis?* (BIS Working Paper No. 583). Bank for International Settlements. https://www.bis.org/publ/work583.pdf

Jobst, A. A., Lin, H. H., & Pradhan, M. (2016). *Negative Interest Rate Policy (NIRP): Implications for Monetary Transmission and Bank Profitability in the Euro Area*. (IMF Working Papers No. 16/172). International Monetary Fund. https://www.imf.org/external/pubs/ft/wp/2016/wp16172.pdf

Johansen, S. 1995. *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford: Oxford University Press.

Jondeau, E., & Sahuc, J. G. (2008). Testing heterogeneity within the euro area. *Economics Letters*, *99*(1), 192-196. https://doi.org/10.1016/j.econlet.2007.06.026

Joyce, M. A., Liu, Z., & Tonks, I. (2017). Institutional investors and the QE portfolio balance channel. *Journal of Money, Credit and Banking*, *49*(6), 1225-1246.

Jud, G. D., & Winkler, D. T. (2003). The Q theory of housing investment. *The Journal of Real Estate Finance and Economics*, *27*(3), 379-392. https://doi.org/10.1023/A:1025846309114

Juselius, M., Borio, C. E., Disyatat, P., & Drehmann, M. (2016). Monetary policy, the financial cycle and ultralow interest rates. (BIS Working Papers No. 569). Bank for International Settlements. https://www.bis.org/publ/work569.htm

Kearns, J., & Patel, N. (2016). Does the financial channel of exchange rates offset the trade channel?. *BIS Quarterly Review*. https://www.bis.org/publ/qtrpdf/r_qt1612i.htm

Kenen, P. B. (1969). The optimum currency area: an eclectic view. In R. A. Mundell & A. K. Swoboda (Ed.). *Monetary problems of the international economy* (pp. 41-60). University of Chicago Press.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. London: Macmillan.

Kiley, M. (2015). *What Can the Data Tell Us About the Equilibrium Real Interest Rate?* (Finance and Economics Discussion Series 2015-77). Washington: Board of Governors of the Federal Reserve System. http://dx.doi.org/10.17016/FEDS.2015.077

Kimball, M. S. (2015). Negative interest rate policy as conventional monetary policy. *National Institute Economic Review, 234*, R5-R14. https://doi.org/10.1177/002795011523400102

Krugman, P. R., Dominquez, K. M., & Rogoff, K. (1998). It's Baaack: Japan's Slump and the Return of the Liquidity Trap. *Brookings Papers on Economic Activity, 1998*(2), 137-206. https://doi.org/10.2307/2534694

Kutasi, G., & Szabó, E. (2019). The effects of negative interest rates on the monetary transmission mechanism – The case of Switzerland, *Köz-Gazdaság, 14*(3), 286-292. https://doi.org/10.14267/RETP2019.03.24

Laubach, T., & Williams, J. C. (2003). Measuring the natural rate of interest. *Review of Economics and Statistics, 85*(4), 1063-1070. https://doi.org/10.1162/003465303772815934

Lilley, A., & Rogoff, K. (2019). The Case for Implementing Effective Negative Interest Rate Policy. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3427388

Lubik, T. A., & Matthes, C. (2015). Calculating the Natural Rate of Interest: A Comparison of Two Alternative Approaches. *Richmond Fed Economic Brief*, 1-6. https://www.richmondfed.org/~/media/richmondfedorg/publications/research/economic_brief/2015/pdf/eb_15-10.pdf

Lütkepohl, H. (2005). *New Introduction to Multiple Time Series Analysis*. New York: Springer.

Mankiw, N. G. (2009, April 18). *It may be time for the fed to go negative*. The New York Times. https://www.nytimes.com/2009/04/19/business/economy/19view.html, Accessed: 08. 03. 2020.

Marques, L. B., Casiraghi, M., Gelos, G., Kamber, G., & Meeks, R. (2021). *Negative interest rates: taking stock of the experience so far*. (IMF Departmental Papers No. 21/03)

International Monetary Fund, Monetary and Capital Markets Department. https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2021/03/01/Negative-Interest-Rates-Taking-Stock-of-the-Experience-So-Far-50115

Martin, E. (2019, August 12). *Danish bank offers mortgages with negative 0.5% interest rates – here's why that's not necessarily a good thing*. CNBC. https://www.cnbc.com/2019/08/12/danish-bank-is-offering-10-year-mortgages-with-negative-interest-rates.html, Accessed: 17. 12. 2022.

McCallum, B. T. (2004). *Monetarism*. Manuscript, Carnegie Mellon University. https://www.econlib.org/library/Enc/Monetarism.html, Accessed: 22. 03. 2020.

McCarthy, J. (2000). Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.249576

McKinnon, R. I. (1963). Optimum currency areas. *American Economic Review, 53*(4), 717-725. https://www.jstor.org/stable/1811021

Melosi, L. (2017). Signalling effects of monetary policy. *The Review of Economic Studies, 84*(2), 853-884.

Meltzer, A. H. (1995). Monetary, credit and (other) transmission processes: a monetarist perspective. *Journal of Economic Perspectives*, *9*(4), 49-72. https://doi.org/10.1257/jep.9.4.49

Mishkin, F. S. (1996). The channels of monetary transmission: lessons for monetary policy (NBER Working Paper Series No. 5464). National Bureau of Economic Research. https://doi.org/10.3386/w5464

Mishkin, F., & Posen, A. (1997). *Inflation targeting: lessons from four countries*. (NBER Working Paper Series No. 6126). National Bureau of Economic Research. https://doi.org/10.3386/w6126

Mishkin, F. S., & Schmidt-Hebbel, K. (2001). *One decade of inflation targeting in the world: What do we know and what do we need to know?*. (NBER Working Paper Series No. 8397). National Bureau of Economic Research. https://doi.org/10.3386/w8397

MNB (2012). *Monetáris politika Magyarországon*. Magyar Nemzeti Bank, https://www.mnb.hu/letoltes/monetaris-politika-magyarorszagon-2012.pdf, Accessed: 02. 11. 2019.

Modigliani, F. (1971). Monetary policy and Consumption: Linkages via Interest Rate and Wealth Effects in the FMP Model. In F. Modigliani, J. Tobin, W. C. Dolde, P. J. Taubman, G. D. Green, D. I. Meiselman et al. (Eds.), *Consumer Spending and Monetary Policy: The Linkages* (pp. 9-84). Conferences Series, No. 5, Boston, MA: Federal Reserve Bank of Boston.

Molyneux, P., Reghezza, A., Thornton, J., & Xie, R. (2020). Did negative interest rates improve bank lending?. *Journal of Financial Services Research, 57*(1), 51-68. https://doi.org/10.1007/s10693-019-00322-8

Mongelli, F. P. (2008). *European economic and monetary integration, and the optimum currency area theory* (Economic Papers No. 302). Directorate General Economic and Financial Affairs (DG ECFIN), European Commission. https://ec.europa.eu/economy_finance/publications/pages/publication12081_en.pdf

Mueller, A. (2018, August 16). *What is money velocity and why does it matter?*. American Institute for Economic Research. https://www.aier.org/article/what-is-money-velocity-and-why-does-it-matter/, Accessed: 08. 03. 2020.

Mundell, R. A. (1961). A theory of optimum currency areas. *The American Economic Review, 51*(4), 657-665. https://www.jstor.org/stable/1812792

Nachane, D. M. (2013). Global Crisis and the New Consensus Macroeconomics: End of "Paradigmatic Determinism?". *Economic and Political Weekly 48*(1), 43-50. https://www.jstor.org/stable/23391136

Nechio, F. (2011). Monetary Policy When One Size Does Not Fit All. *FRBSF Economic Letter*, *2011*, 18. https://www.frbsf.org/research-and-insights/publications/economic-letter/2011/06/monetary-policy-europe/

Newcomb, S. (1885). *Principles of Political Economy*. Harper & Brothers

Niehans, J. (1987). Classical monetary theory, new and old. *Journal of Money, Credit and Banking*, *19*(4), 409-424. https://doi.org/10.2307/1992610

Nucera, F., Lucas, A., Schaumburg, J., & Schwaab, B. (2017). Do negative interest rates make banks less safe?. *Economics Letters*, *159*, 112-115. https://doi.org/10.1016/j.econlet.2017.07.014

Özyurt, S. (2016). *Has the exchange rate pass through recently declined in the euro area?* (ECB Working Paper Series No. 1955). European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1955.en.pdf

Paul, P. (2020). The time-varying effect of monetary policy on asset prices. *Review of Economics and Statistics, 102*(4), 690-704.

Pilkington, P. (2014, March 22). *Monetarism is the living dead of economic theory – let's kill it off*. The Guardian, https://www.theguardian.com/commentisfree/2014/mar/22/monetarism-economic-theory-bank-of-england-government, Accessed: 21. 03. 2020.

Priftis, R., & Vogel, L. (2016). The portfolio balance mechanism and QE in the euro area. *The Manchester School, 84*(S1), 84-105.

Repullo, R. (2020). *The Reversal Interest Rate: A Critical Review*. (CEPR Discussion Papers No. 15367). Centre for Economic Policy Research. https://cepr.org/publications/dp15367

Robson, P. (1987). *The Economics of International Integration*. London: Allen and Unwin.

Rose, A. K. (2000). One money, one market: the effect of common currencies on trade. *Economic policy, 15*(30), 08-45. https://doi.org/10.1111/1468-0327.00056

Rose, A. K., & Stanley, T. D. (2005). A meta-analysis of the effect of common currencies on international trade. *Journal of Economic Surveys, 19*(3), 347-365. https://doi.org/10.1111/j.0950-0804.2005.00251.x

Rostagno, M., Altavilla, C., Carboni, G., Lemke, W., Motto, R., & Guilhem, A. S. (2021). Combining negative rates, forward guidance and asset purchases: identification and impacts of the ECB's unconventional policies. (ECB Working Paper Series No. 2564) European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2564~e02f3aad4c.cs.pdf

Rotemberg, J. J. (1982). Sticky prices in the United States. *Journal of Political Economy, 90*(6), 1187-1211. https://doi.org/10.1086/261117

Rupert, P., & Šustek, R. (2019). On the mechanics of New-Keynesian models. *Journal of Monetary Economics, 102*, 53-69. https://doi.org/10.1016/j.jmoneco.2019.01.024

Sander, H. – Kleimeier, S. (2004). Convergence in euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission, competition and integration. *Journal of International Money and Finance*, *23*(3), 461-492. https://doi.org/10.1016/j.jimonfin.2004.02.001

Sapir, A. (2016). The Eurozone needs less heterogeneity. In: Baldwin, R. E., & Giavazzi, F. *How to fix Europe's monetary union: Views of leading economists*, VoxEU.org eBook, CEPR Press. 180-187.

Sau, L. (2018). Coping with deflation and the liquidity trap in the eurozone: A post Keynesian approach. *Journal of Post Keynesian Economics*, *41*(2), 210-235. https://doi.org/10.1080/01603477.2017.1387498

Sellon, G. H. (2002). The changing US financial system: some implications for the monetary transmission mechanism. *Economic Review, Federal Reserve Bank of Kansas City*, *87*(1), 5-35. https://ideas.repec.org/a/fip/fedker/y2002iqip5-35nv.87no.1.html

Seltmann, T. (2010). Umlaufsicherung von Banknoten. *Humane Wirtschaft*, *2*(2010), 10-16. https://humane-wirtschaft.de/wp-content/uploads/2010/02/Seltmann-Umlaufsicherung_von_Banknoten.pdf

SNB. (2014, December 18). *Swiss National Bank introduces negative interest rates* [Press Release]. https://www.snb.ch/en/mmr/reference/pre_20141218/source/pre_20141218.en.pdf, Accessed: 26. 04. 2020.

Spolaore, E. (2013). What is European integration really about? A political guide for economists. *Journal of Economic Perspectives*, *27*(3), 125-144.

Summers, L. H. (2016). The age of secular stagnation: What it is and what to do about it. *Foreign Affairs*, *95*(2), 2-9. https://www.jstor.org/stable/43948172

Takhtamanova, Y. F. (2010). Understanding changes in exchange rate pass-through. *Journal of Macroeconomics*, *32*(4), 1118-1130. https://doi.org/10.1016/j.jmacro.2010.04.004

Tavlas, G. S. (1993). The ‘new’ theory of optimum currency areas. *World Economy*, *16*(6), 663-685. https://doi.org/10.1111/j.1467-9701.1993.tb00189.x

Tavlas, G. S. (1994). The theory of monetary integration. *Open Economies Review*, *5*(2), 211-230. https://doi.org/10.1007/bf01000489

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy, 39*, 195-214. https://doi.org/10.1016/0167-2231(93)90009-l

Thornton, J., & Vasilakis, C. (2019). Negative policy interest rates and exchange rate behavior: Further results. *Finance Research Letters*, *29*, 61-67. https://doi.org/10.1016/j.frl.2019.03.023

Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking, 1*(1), 15-29. https://doi.org/10.2307/1991374

Tsatsaronis, C. (1995). *Is there a credit channel in the transmission of monetary policy? Evidence from four countries*. BIS, Financial Structure and the Monetary Policy Transmission Mechanism, CB Document, 394, 154-187. https://www.bis.org/publ/bppdf/bispap00d.pdf

Udland, M. (2016, March 15). *Europe may still be stuck in a liquidity trap*. Business Insider, https://www.businessinsider.com/europe-liquidity-trap-2016-3, Accessed: 15. 03. 2020.

Vaggi, G., & Groenewegen, P. (2016). *A concise history of economic thought: From mercantilism to monetarism.* Springer.

von Hagen, J. (1998). Money growth targeting. In *IIES Conference on Monetary Policy Rules*. Sveriges Riksbank and Institute for International Economic Studies. Stockholm University. https://larseosvensson.se/files/conf/vonhag.pdf

Walsh, C. E. (2009). Inflation targeting: what have we learned?. *International Finance, 12*(2), 195-233. https://doi.org/10.1111/j.1468-2362.2009.01236.x

Warner, J. (2010). Stamp script in the great depression: lessons for community currency for today. *International Journal of Community Currency Research*, *14*, 29-45. http://dx.doi.org/10.15133/j.ijccr.2010.004

Wass, S. (2020, September 23). *Nordea expands negative interest rates on deposits in Denmark*. S&P Global. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/nordea-expands-negative-interest-rates-on-deposits-in-denmark-60444307, Accessed: 17. 12. 2022.

Wicksell, K. (1898). *Interest and prices*. R. F. Kahn (trans.) Kelley: New York, 1965.

Williams, J. C. (2015). The Decline in the Natural Rate of Interest. *Business Economics*, *50*(2), 57-60. https://doi.org/10.1057/be.2015.11

Woodford, M. (2005). *Central bank communication and policy effectiveness* (NBER Working Paper Series No. 11898). National Bureau of Economic Research. https://doi.org/10.3386/w11898

Woodford, M. (2012). *Inflation targeting and financial stability* (NBER Working Paper Series No. 17967). National Bureau of Economic Research. https://doi.org/10.3386/w17967

Woodford, M. (2013). *Macroeconomic Analysis Without the Rational Expectations Hypothesis* (NBER Working Paper No. 19368). National Bureau of Economic Research. https://doi.org/10.3386/w19368

Wooldridge, J. M. (2015). *Introductory econometrics: A modern approach*. Cengage Learning.

Yun, Y., & Cho, B. (2022). Does monetary policy affect bank lending to households and firms differently?. *Economic Modelling*, *109*, 105783.

Zlobins, A. (2021). Macroeconomic effects of the ECB's forward guidance. *Empirical Economics*, *61*, 2587-2611. https://doi.org/10.1007/s00181-020-01981-6

Data

ECB (2022a). *12-month Euribor*. https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=143.FM.M.U2.EUR.RT.MM.EURIBOR1YD_.HSTA

ECB (2022b). *3-month Euribor*. https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=143.FM.M.U2.EUR.RT.MM.EURIBOR3MD_.HSTA

ECB (2022c). *6-month Euribor*. https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=143.FM.M.U2.EUR.RT.MM.EURIBOR6MD_.HSTA

ECB (2022d). *ECB assets*. https://sdw.ecb.europa.eu/browse.do?node=9691311

ECB (2022e). *Cost of borrowing indicators*. https://sdw.ecb.europa.eu/browse.do?node=9691390

ECB (2022f). *Key ECB interest rates.* https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html

ECB (2022g). *Monetary aggregates.* https://sdw.ecb.europa.eu/browse.do?node=9691114

Eurostat (2022a). *Exchange rate*. https://ec.europa.eu/eurostat/databrowser/view/ert_bil_eur_m/default/table?lang=en

Eurostat (2022b). *Inflation*. https://ec.europa.eu/eurostat/databrowser/view/prc_hicp_midx/default/table?lang=en

Eurostat (2022c). *Production in industry*. https://ec.europa.eu/eurostat/databrowser/view/sts_inpr_m/default/table?lang=en

Eurostat (2022d). *Unemployment*. https://ec.europa.eu/eurostat/databrowser/view/une_rt_m/default/table?lang=en

Appendix

Table 32: Summary statistics - Inflation

Inflation						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Austria	235	95.48	96.55	10.47	78.71	121.67
Belgium	235	96.34	97.82	10.54	77.51	122.82
Cyprus	235	95.63	98.53	7.19	79.85	113.22
Estonia	235	93.06	97.16	16.71	64.36	141.73
Finland	235	94.67	97.58	8.83	80.76	114.49
France	235	96.70	98.56	7.65	81.87	114.94
Germany	235	96.40	97.40	8.46	82.00	119.00
Greece	235	96.58	100.16	8.04	77.32	114.05
Ireland	235	98.00	99.40	4.77	85.70	113.40
Italy	235	95.28	98.20	8.23	78.50	114.10
Latvia	235	93.20	98.85	16.59	58.58	135.95
Lithuania	235	94.88	99.42	15.51	68.46	139.36
Luxembourg	235	94.99	98.11	10.60	74.29	120.65
Malta	235	94.81	96.58	9.90	74.91	117.39
Netherlands	235	96.48	97.70	8.79	82.07	122.74
Portugal	235	96.28	98.78	7.47	80.75	114.39
Slovakia	235	95.83	99.27	10.87	72.50	126.02
Slovenia	235	95.35	98.91	9.71	74.64	119.63
Spain	235	96.03	99.16	8.93	76.94	118.22
Euro Area	235	96.14	98.36	8.44	80.14	117.14

Notes: Index, 2015=100, all items HICP.
Source: Constructed by the author based on Eurostat data

Table 33: Summary statistics - Industrial production

Industrial production						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Austria	235	97.76	97.10	12.83	73.30	130.70
Belgium	235	100.19	100.50	12.91	74.20	139.10
Cyprus	235	124.26	130.70	15.43	83.80	152.30
Estonia	235	92.96	94.00	20.15	57.30	130.60
Finland	235	108.71	107.50	7.12	97.30	128.30
France	235	103.10	101.70	6.16	67.80	115.90
Germany	235	95.11	97.40	7.05	71.40	107.00
Greece	235	118.44	111.40	17.02	95.30	149.90
Ireland	235	80.63	65.30	27.79	49.70	174.60
Italy	235	109.35	105.80	11.28	58.20	133.30
Latvia	235	98.33	96.60	14.65	72.30	126.50
Lithuania	235	98.51	95.00	20.35	58.20	171.00
Luxembourg	235	102.51	100.80	8.80	67.80	123.00
Malta	235	105.50	105.00	7.41	89.60	128.10
Netherlands	235	102.03	104.20	3.79	89.10	114.20
Portugal	235	106.49	103.40	9.80	74.40	128.30
Slovakia	235	87.51	89.80	20.87	49.50	120.20
Slovenia	235	102.76	97.30	14.53	81.20	136.80
Spain	235	110.07	105.40	13.34	69.50	136.90
Euro Area	235	100.25	100.20	5.06	75.10	110.10

Notes: Index, 2015=100.
Source: Constructed by the author based on Eurostat data

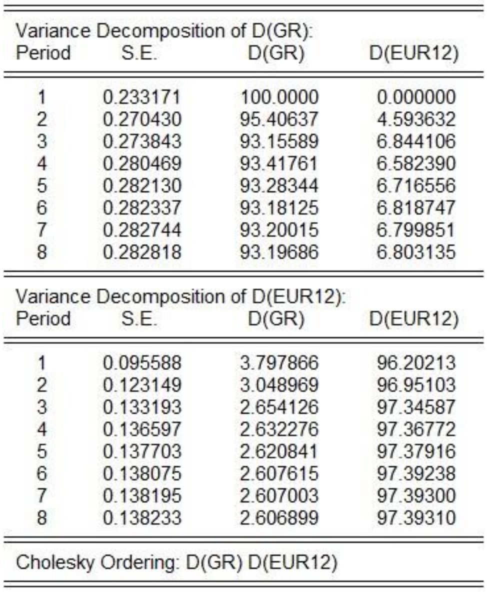
Table 34: Summary statistics - Unemployment

Unemployment						
Variable	**Observations**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Austria	235	5.53	5.50	0.71	3.90	7.90
Belgium	235	7.49	7.80	1.10	5.10	9.00
Cyprus	235	8.34	6.90	4.09	3.40	16.80
Estonia	235	8.07	7.00	3.30	3.90	19.20
Finland	235	8.04	8.20	0.95	5.70	9.90
France	235	8.99	9.00	0.91	7.10	10.50
Germany	235	6.04	5.00	2.64	2.90	11.20
Greece	235	16.54	16.50	6.70	7.40	28.10
Ireland	235	8.43	6.60	4.02	4.20	16.10
Italy	235	9.41	9.00	1.98	5.90	13.30
Latvia	235	10.55	9.80	3.92	5.30	20.70
Lithuania	235	9.50	8.90	3.71	4.00	18.30
Luxembourg	235	5.24	5.10	0.81	3.20	7.50
Malta	235	5.62	6.00	1.40	2.90	8.50
Netherlands	235	6.02	6.00	1.31	3.20	8.70
Portugal	235	10.40	9.40	3.28	5.70	18.30
Slovakia	235	11.56	12.00	3.82	5.70	19.10
Slovenia	235	6.64	6.40	1.84	3.90	10.80
Spain	235	16.35	15.90	5.55	7.90	26.40
Euro Area	235	9.31	9.20	1.49	6.60	12.20

Notes: Percentage.
Source: Constructed by the author based on Eurostat data

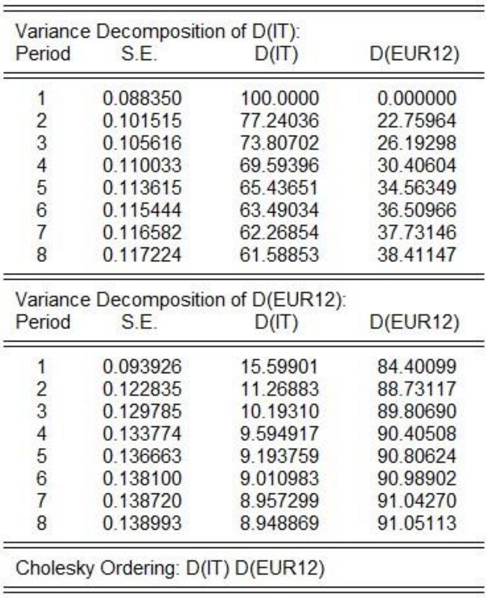
Table 35: Variance decomposition table of corporates' cost of borrowing - Dummy models

Greece



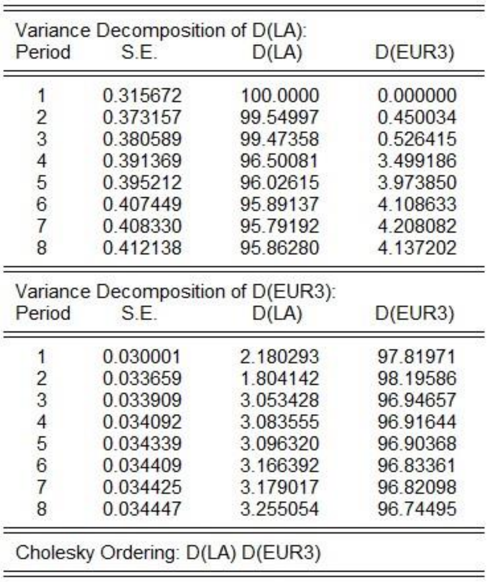
```
Variance Decomposition of D(GR):
Period      S.E.        D(GR)       D(EUR12)

  1       0.233171    100.0000    0.000000
  2       0.270430    95.40637    4.593632
  3       0.273843    93.15589    6.844106
  4       0.280469    93.41761    6.582390
  5       0.282130    93.28344    6.716556
  6       0.282337    93.18125    6.818747
  7       0.282744    93.20015    6.799851
  8       0.282818    93.19686    6.803135

Variance Decomposition of D(EUR12):
Period      S.E.        D(GR)       D(EUR12)

  1       0.095588    3.797866    96.20213
  2       0.123149    3.048969    96.95103
  3       0.133193    2.654126    97.34587
  4       0.136597    2.632276    97.36772
  5       0.137703    2.620841    97.37916
  6       0.138075    2.607615    97.39238
  7       0.138195    2.607003    97.39300
  8       0.138233    2.606899    97.39310

Cholesky Ordering: D(GR) D(EUR12)
```

Italy



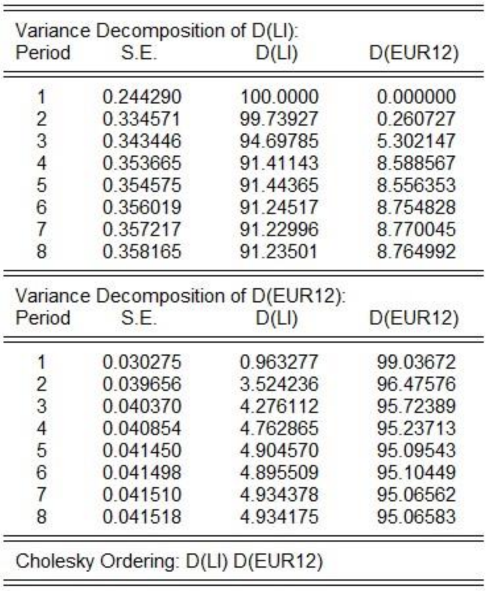
```
Variance Decomposition of D(IT):
Period      S.E.        D(IT)       D(EUR12)

  1       0.088350    100.0000    0.000000
  2       0.101515    77.24036    22.75964
  3       0.105616    73.80702    26.19298
  4       0.110033    69.59396    30.40604
  5       0.113615    65.43651    34.56349
  6       0.115444    63.49034    36.50966
  7       0.116582    62.26854    37.73146
  8       0.117224    61.58853    38.41147

Variance Decomposition of D(EUR12):
Period      S.E.        D(IT)       D(EUR12)

  1       0.093926    15.59901    84.40099
  2       0.122835    11.26883    88.73117
  3       0.129785    10.19310    89.80690
  4       0.133774    9.594917    90.40508
  5       0.136663    9.193759    90.80624
  6       0.138100    9.010983    90.98902
  7       0.138720    8.957299    91.04270
  8       0.138993    8.948869    91.05113

Cholesky Ordering: D(IT) D(EUR12)
```

Latvia



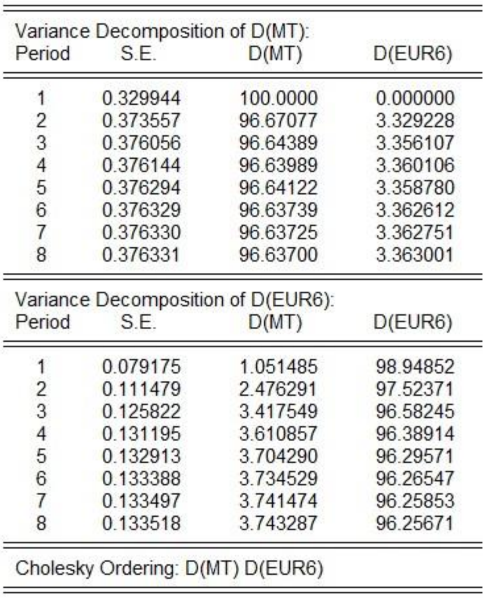
```
Variance Decomposition of D(LA):
Period      S.E.        D(LA)       D(EUR3)

  1       0.315672    100.0000    0.000000
  2       0.373157    99.54997    0.450034
  3       0.380589    99.47358    0.526415
  4       0.391369    96.50081    3.499186
  5       0.395212    96.02615    3.973850
  6       0.407449    95.89137    4.108633
  7       0.408330    95.79192    4.208082
  8       0.412138    95.86280    4.137202

Variance Decomposition of D(EUR3):
Period      S.E.        D(LA)       D(EUR3)

  1       0.030001    2.180293    97.81971
  2       0.033659    1.804142    98.19586
  3       0.033909    3.053428    96.94657
  4       0.034092    3.083555    96.91644
  5       0.034339    3.096320    96.90368
  6       0.034409    3.166392    96.83361
  7       0.034425    3.179017    96.82098
  8       0.034447    3.255054    96.74495

Cholesky Ordering: D(LA) D(EUR3)
```

Lithuania



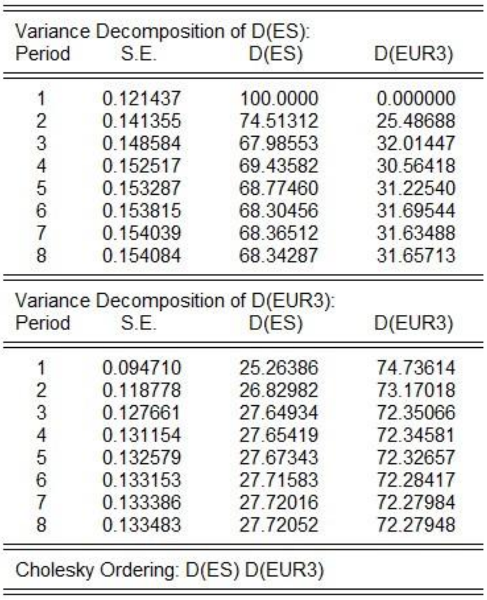
```
Variance Decomposition of D(LI):
Period      S.E.        D(LI)       D(EUR12)

  1       0.244290    100.0000    0.000000
  2       0.334571    99.73927    0.260727
  3       0.343446    94.69785    5.302147
  4       0.353665    91.41143    8.588567
  5       0.354575    91.44365    8.556353
  6       0.356019    91.24517    8.754828
  7       0.357217    91.22996    8.770045
  8       0.358165    91.23501    8.764992

Variance Decomposition of D(EUR12):
Period      S.E.        D(LI)       D(EUR12)

  1       0.030275    0.963277    99.03672
  2       0.039656    3.524236    96.47576
  3       0.040370    4.276112    95.72389
  4       0.040854    4.762865    95.23713
  5       0.041450    4.904570    95.09543
  6       0.041498    4.895509    95.10449
  7       0.041510    4.934378    95.06562
  8       0.041518    4.934175    95.06583

Cholesky Ordering: D(LI) D(EUR12)
```

Malta



```
Variance Decomposition of D(MT):
Period      S.E.        D(MT)       D(EUR6)

  1       0.329944    100.0000    0.000000
  2       0.373557    96.67077    3.329228
  3       0.376056    96.64389    3.356107
  4       0.376144    96.63989    3.360106
  5       0.376294    96.64122    3.358780
  6       0.376329    96.63739    3.362612
  7       0.376330    96.63725    3.362751
  8       0.376331    96.63700    3.363001

Variance Decomposition of D(EUR6):
Period      S.E.        D(MT)       D(EUR6)

  1       0.079175    1.051485    98.94852
  2       0.111479    2.476291    97.52371
  3       0.125822    3.417549    96.58245
  4       0.131195    3.610857    96.38914
  5       0.132913    3.704290    96.29571
  6       0.133388    3.734529    96.26547
  7       0.133497    3.741474    96.25853
  8       0.133518    3.743287    96.25671

Cholesky Ordering: D(MT) D(EUR6)
```

Spain

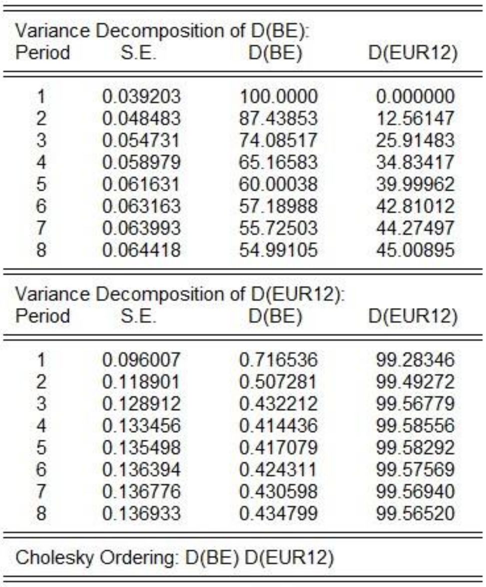


```
Variance Decomposition of D(ES):
Period      S.E.        D(ES)       D(EUR3)

  1       0.121437    100.0000    0.000000
  2       0.141355    74.51312    25.48688
  3       0.148584    67.98553    32.01447
  4       0.152517    69.43582    30.56418
  5       0.153287    68.77460    31.22540
  6       0.153815    68.30456    31.69544
  7       0.154039    68.36512    31.63488
  8       0.154084    68.34287    31.65713

Variance Decomposition of D(EUR3):
Period      S.E.        D(ES)       D(EUR3)

  1       0.094710    25.26386    74.73614
  2       0.118778    26.82982    73.17018
  3       0.127661    27.64934    72.35066
  4       0.131154    27.65419    72.34581
  5       0.132579    27.67343    72.32657
  6       0.133153    27.71583    72.28417
  7       0.133386    27.72016    72.27984
  8       0.133483    27.72052    72.27948

Cholesky Ordering: D(ES) D(EUR3)
```

Notes: The variables are coded as follows EUR3 = 3-month Euribor, EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, GR = Greece, IT = Italy, LA = Latvia, LI = Lithuania, MT = Malta and ES = Spain. 'D' refers to the first difference of the variable.
Source: Estimation by the author based on ECB data

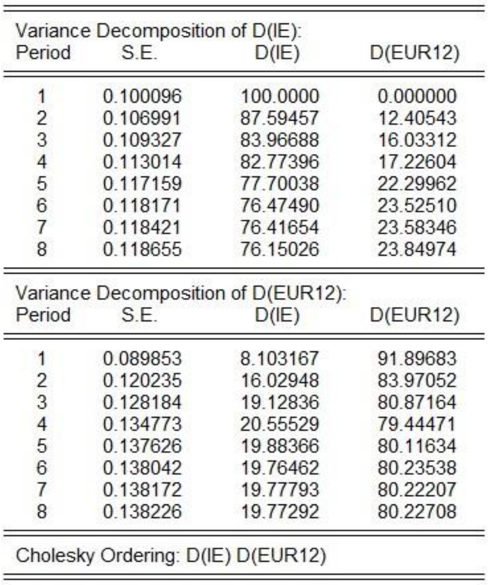
Table 36: Variance decomposition table of households' cost of borrowing - Dummy models

Belgium



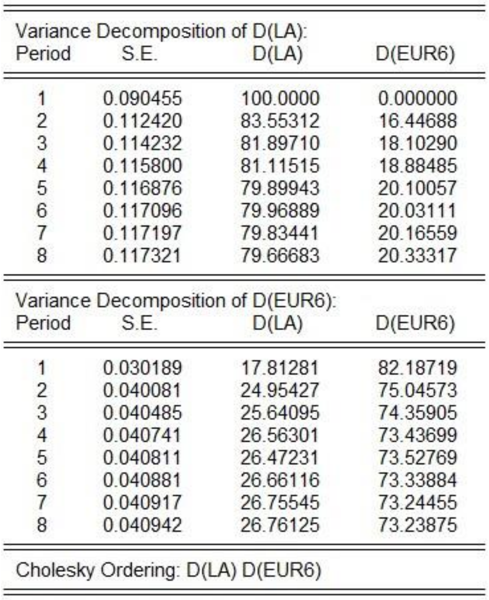
```
Variance Decomposition of D(BE):
Period      S.E.        D(BE)       D(EUR12)

  1       0.039203    100.0000    0.000000
  2       0.048483    87.43853    12.56147
  3       0.054731    74.08517    25.91483
  4       0.058979    65.16583    34.83417
  5       0.061631    60.00038    39.99962
  6       0.063163    57.18988    42.81012
  7       0.063993    55.72503    44.27497
  8       0.064418    54.99105    45.00895

Variance Decomposition of D(EUR12):
Period      S.E.        D(BE)       D(EUR12)

  1       0.096007    0.716536    99.28346
  2       0.118901    0.507281    99.49272
  3       0.128912    0.432212    99.56779
  4       0.133456    0.414436    99.58556
  5       0.135498    0.417079    99.58292
  6       0.136394    0.424311    99.57569
  7       0.136776    0.430598    99.56940
  8       0.136933    0.434799    99.56520

Cholesky Ordering: D(BE) D(EUR12)
```

Ireland



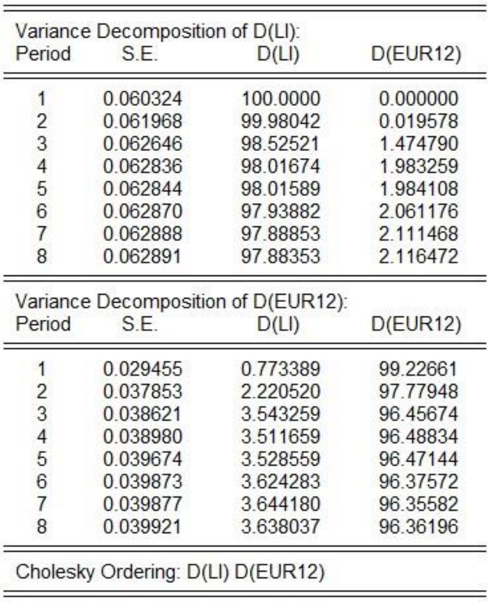
```
Variance Decomposition of D(IE):
Period      S.E.        D(IE)       D(EUR12)

  1       0.100096    100.0000    0.000000
  2       0.106991    87.59457    12.40543
  3       0.109327    83.96688    16.03312
  4       0.113014    82.77396    17.22604
  5       0.117159    77.70038    22.29962
  6       0.118171    76.47490    23.52510
  7       0.118421    76.41654    23.58346
  8       0.118655    76.15026    23.84974

Variance Decomposition of D(EUR12):
Period      S.E.        D(IE)       D(EUR12)

  1       0.089853    8.103167    91.89683
  2       0.120235    16.02948    83.97052
  3       0.128184    19.12836    80.87164
  4       0.134773    20.55529    79.44471
  5       0.137626    19.88366    80.11634
  6       0.138042    19.76462    80.23538
  7       0.138172    19.77793    80.22207
  8       0.138226    19.77292    80.22708

Cholesky Ordering: D(IE) D(EUR12)
```

Latvia



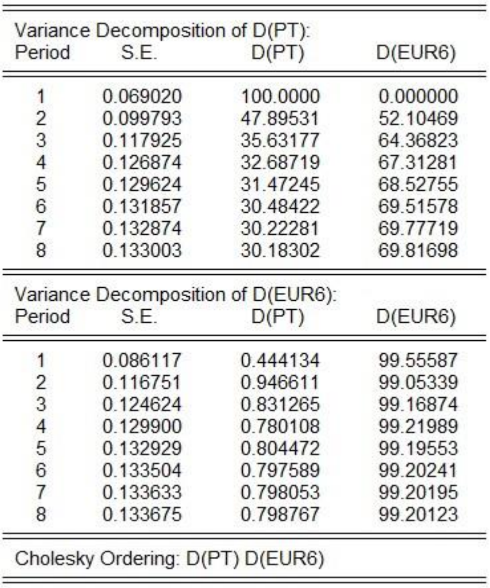
```
Variance Decomposition of D(LA):
Period      S.E.        D(LA)       D(EUR6)

  1       0.090455    100.0000    0.000000
  2       0.112420    83.55312    16.44688
  3       0.114232    81.89710    18.10290
  4       0.115800    81.11515    18.88485
  5       0.116876    79.89943    20.10057
  6       0.117096    79.96889    20.03111
  7       0.117197    79.83441    20.16559
  8       0.117321    79.66683    20.33317

Variance Decomposition of D(EUR6):
Period      S.E.        D(LA)       D(EUR6)

  1       0.030189    17.81281    82.18719
  2       0.040081    24.95427    75.04573
  3       0.040485    25.64095    74.35905
  4       0.040741    26.56301    73.43699
  5       0.040811    26.47231    73.52769
  6       0.040881    26.66116    73.33884
  7       0.040917    26.75545    73.24455
  8       0.040942    26.76125    73.23875

Cholesky Ordering: D(LA) D(EUR6)
```

Lithuania



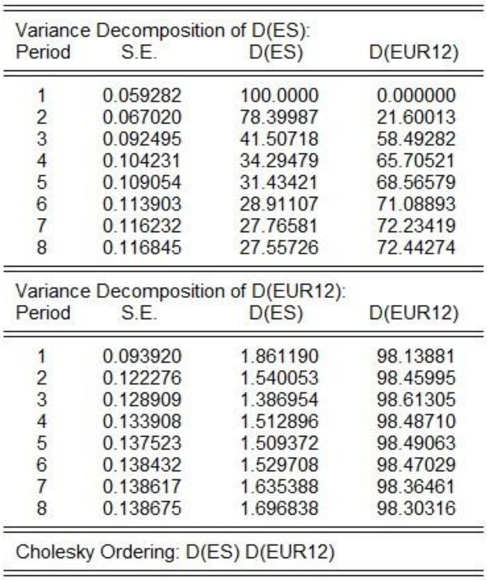
```
Variance Decomposition of D(LI):
Period      S.E.        D(LI)       D(EUR12)

  1       0.060324    100.0000    0.000000
  2       0.061968    99.98042    0.019578
  3       0.062646    98.52521    1.474790
  4       0.062836    98.01674    1.983259
  5       0.062844    98.01589    1.984108
  6       0.062870    97.93882    2.061176
  7       0.062888    97.88853    2.111468
  8       0.062891    97.88353    2.116472

Variance Decomposition of D(EUR12):
Period      S.E.        D(LI)       D(EUR12)

  1       0.029455    0.773389    99.22661
  2       0.037853    2.220520    97.77948
  3       0.038621    3.543259    96.45674
  4       0.038980    3.511659    96.48834
  5       0.039674    3.528559    96.47144
  6       0.039873    3.624283    96.37572
  7       0.039877    3.644180    96.35582
  8       0.039921    3.638037    96.36196

Cholesky Ordering: D(LI) D(EUR12)
```

Portugal



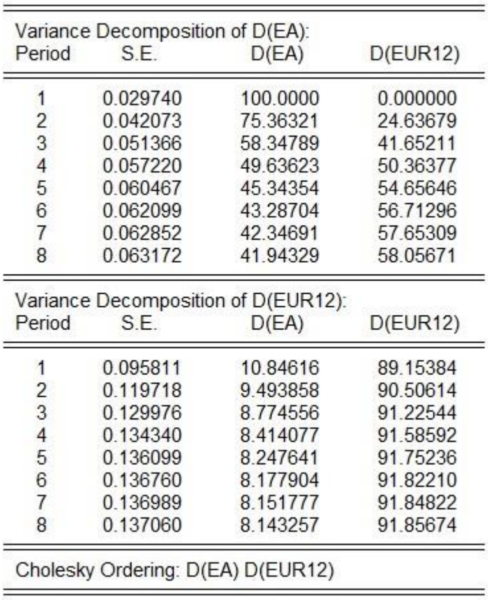
```
Variance Decomposition of D(PT):
Period      S.E.        D(PT)       D(EUR6)

  1       0.069020    100.0000    0.000000
  2       0.099793    47.89531    52.10469
  3       0.117925    35.63177    64.36823
  4       0.126874    32.68719    67.31281
  5       0.129624    31.47245    68.52755
  6       0.131857    30.48422    69.51578
  7       0.132874    30.22281    69.77719
  8       0.133003    30.18302    69.81698

Variance Decomposition of D(EUR6):
Period      S.E.        D(PT)       D(EUR6)

  1       0.086117    0.444134    99.55587
  2       0.116751    0.946611    99.05339
  3       0.124624    0.831265    99.16874
  4       0.129900    0.780108    99.21989
  5       0.132929    0.804472    99.19553
  6       0.133504    0.797589    99.20241
  7       0.133633    0.798053    99.20195
  8       0.133675    0.798767    99.20123

Cholesky Ordering: D(PT) D(EUR6)
```

Spain



```
Variance Decomposition of D(ES):
Period      S.E.        D(ES)       D(EUR12)

  1       0.059282    100.0000    0.000000
  2       0.067020    78.39987    21.60013
  3       0.092495    41.50718    58.49282
  4       0.104231    34.29479    65.70521
  5       0.109054    31.43421    68.56579
  6       0.113903    28.91107    71.08893
  7       0.116232    27.76581    72.23419
  8       0.116845    27.55726    72.44274

Variance Decomposition of D(EUR12):
Period      S.E.        D(ES)       D(EUR12)

  1       0.093920    1.861190    98.13881
  2       0.122276    1.540053    98.45995
  3       0.128909    1.386954    98.61305
  4       0.133908    1.512896    98.48710
  5       0.137523    1.509372    98.49063
  6       0.138432    1.529708    98.47029
  7       0.138617    1.635388    98.36461
  8       0.138675    1.696838    98.30316

Cholesky Ordering: D(ES) D(EUR12)
```

Euro Area



Variance Decomposition of D(EA):

Period	S.E.	D(EA)	D(EUR12)
1	0.029740	100.0000	0.000000
2	0.042073	75.36321	24.63679
3	0.051366	58.34789	41.65211
4	0.057220	49.63623	50.36377
5	0.060467	45.34354	54.65646
6	0.062099	43.28704	56.71296
7	0.062852	42.34691	57.65309
8	0.063172	41.94329	58.05671

Variance Decomposition of D(EUR12):

Period	S.E.	D(EA)	D(EUR12)
1	0.095811	10.84616	89.15384
2	0.119718	9.493858	90.50614
3	0.129976	8.774556	91.22544
4	0.134340	8.414077	91.58592
5	0.136099	8.247641	91.75236
6	0.136760	8.177904	91.82210
7	0.136989	8.151777	91.84822
8	0.137060	8.143257	91.85674

Cholesky Ordering: D(EA) D(EUR12)

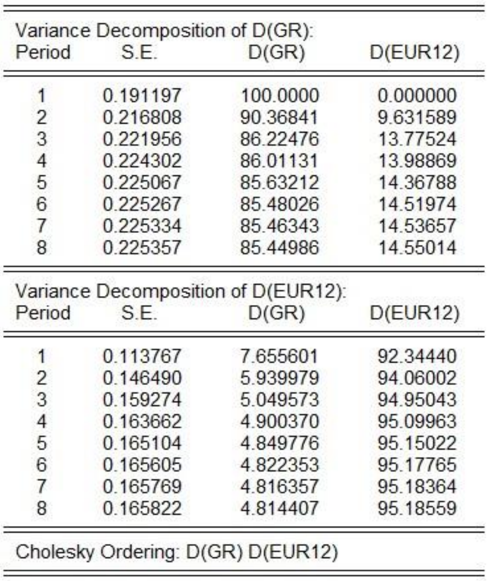
Notes: The variables are coded as follows EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, BE = Belgium, IE = Ireland, LA = Latvia, LI = Lithuania, PT = Portugal, ES = Spain and EA = Euro Area. 'D' refers to the first difference of the variable. Response to Cholesky one S.D. innovations +/- 2 S.E.

Source: Estimation by the author based on ECB data

Table 37: Variance decomposition table of corporates' cost of borrowing – Two period models

1st period

Greece



Variance Decomposition of D(GR):

Period	S.E.	D(GR)	D(EUR12)
1	0.191197	100.0000	0.000000
2	0.216808	90.36841	9.631589
3	0.221956	86.22476	13.77524
4	0.224302	86.01131	13.98869
5	0.225067	85.63212	14.36788
6	0.225267	85.48026	14.51974
7	0.225334	85.46343	14.53657
8	0.225357	85.44986	14.55014

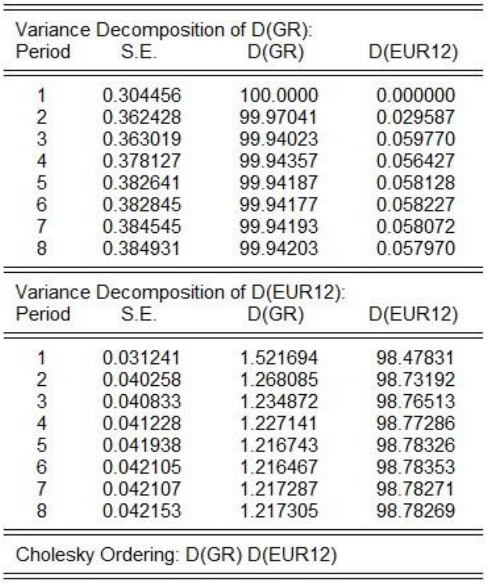
Variance Decomposition of D(EUR12):

Period	S.E.	D(GR)	D(EUR12)
1	0.113767	7.655601	92.34440
2	0.146490	5.939979	94.06002
3	0.159274	5.049573	94.95043
4	0.163662	4.900370	95.09963
5	0.165104	4.849776	95.15022
6	0.165605	4.822353	95.17765
7	0.165769	4.816357	95.18364
8	0.165822	4.814407	95.18559

Cholesky Ordering: D(GR) D(EUR12)

2nd period

Greece



Variance Decomposition of D(GR):

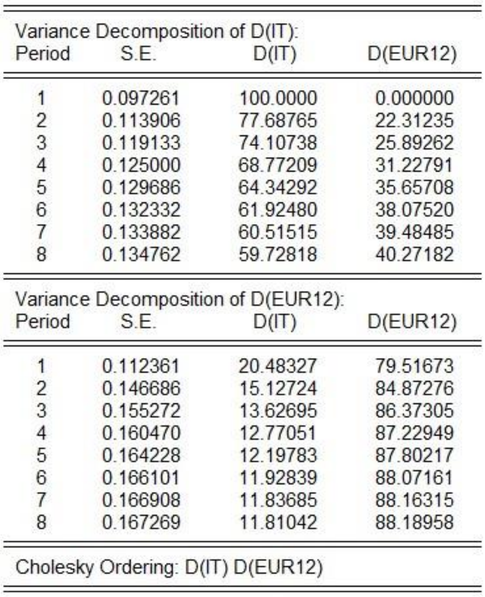
Period	S.E.	D(GR)	D(EUR12)
1	0.304456	100.0000	0.000000
2	0.362428	99.97041	0.029587
3	0.363019	99.94023	0.059770
4	0.378127	99.94357	0.056427
5	0.382641	99.94187	0.058128
6	0.382845	99.94177	0.058227
7	0.384545	99.94193	0.058072
8	0.384931	99.94203	0.057970

Variance Decomposition of D(EUR12):

Period	S.E.	D(GR)	D(EUR12)
1	0.031241	1.521694	98.47831
2	0.040258	1.268085	98.73192
3	0.040833	1.234872	98.76513
4	0.041228	1.227141	98.77286
5	0.041938	1.216743	98.78326
6	0.042105	1.216467	98.78353
7	0.042107	1.217287	98.78271
8	0.042153	1.217305	98.78269

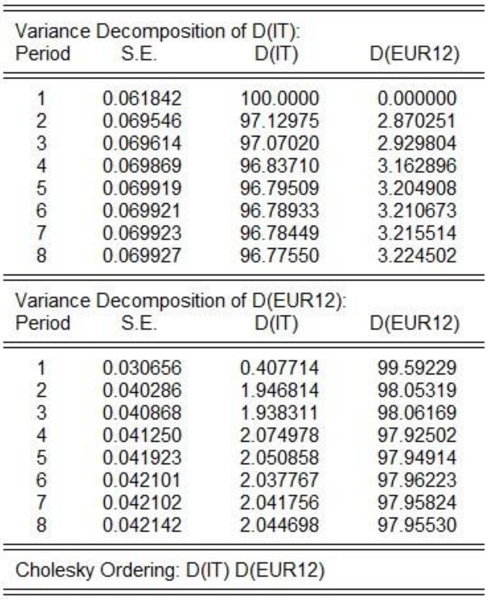
Cholesky Ordering: D(GR) D(EUR12)

Italy



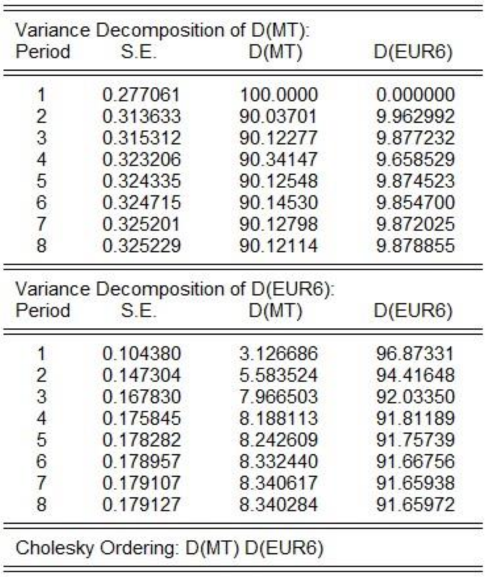
```
Variance Decomposition of D(IT):
Period      S.E.        D(IT)       D(EUR12)

  1       0.097261    100.0000    0.000000
  2       0.113906    77.68765    22.31235
  3       0.119133    74.10738    25.89262
  4       0.125000    68.77209    31.22791
  5       0.129686    64.34292    35.65708
  6       0.132332    61.92480    38.07520
  7       0.133882    60.51515    39.48485
  8       0.134762    59.72818    40.27182

Variance Decomposition of D(EUR12):
Period      S.E.        D(IT)       D(EUR12)

  1       0.112361    20.48327    79.51673
  2       0.146686    15.12724    84.87276
  3       0.155272    13.62695    86.37305
  4       0.160470    12.77051    87.22949
  5       0.164228    12.19783    87.80217
  6       0.166101    11.92839    88.07161
  7       0.166908    11.83685    88.16315
  8       0.167269    11.81042    88.18958

Cholesky Ordering: D(IT) D(EUR12)
```

Italy



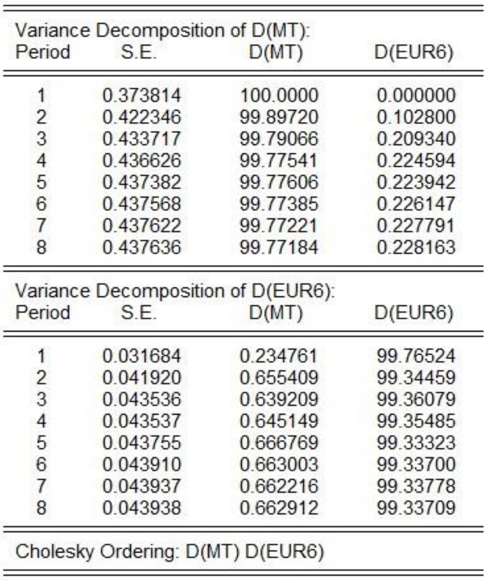
```
Variance Decomposition of D(IT):
Period      S.E.        D(IT)       D(EUR12)

  1       0.061842    100.0000    0.000000
  2       0.069546    97.12975    2.870251
  3       0.069614    97.07020    2.929804
  4       0.069869    96.83710    3.162896
  5       0.069919    96.79509    3.204908
  6       0.069921    96.78933    3.210673
  7       0.069923    96.78449    3.215514
  8       0.069927    96.77550    3.224502

Variance Decomposition of D(EUR12):
Period      S.E.        D(IT)       D(EUR12)

  1       0.030656    0.407714    99.59229
  2       0.040286    1.946814    98.05319
  3       0.040868    1.938311    98.06169
  4       0.041250    2.074978    97.92502
  5       0.041923    2.050858    97.94914
  6       0.042101    2.037767    97.96223
  7       0.042102    2.041756    97.95824
  8       0.042142    2.044698    97.95530

Cholesky Ordering: D(IT) D(EUR12)
```

Malta



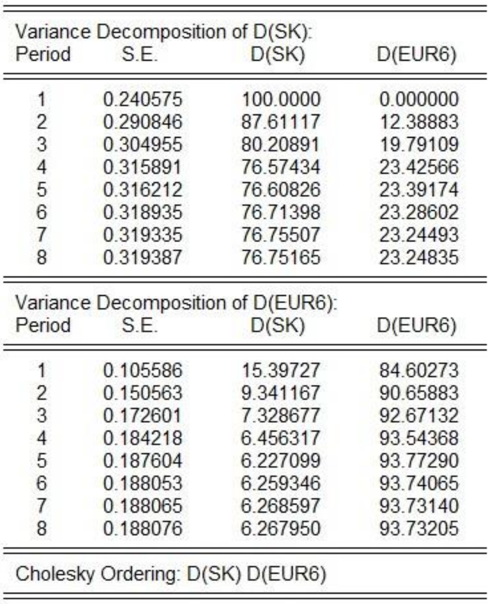
```
Variance Decomposition of D(MT):
Period      S.E.        D(MT)       D(EUR6)

  1       0.277061    100.0000    0.000000
  2       0.313633    90.03701    9.962992
  3       0.315312    90.12277    9.877232
  4       0.323206    90.34147    9.658529
  5       0.324335    90.12548    9.874523
  6       0.324715    90.14530    9.854700
  7       0.325201    90.12798    9.872025
  8       0.325229    90.12114    9.878855

Variance Decomposition of D(EUR6):
Period      S.E.        D(MT)       D(EUR6)

  1       0.104380    3.126686    96.87331
  2       0.147304    5.583524    94.41648
  3       0.167830    7.966503    92.03350
  4       0.175845    8.188113    91.81189
  5       0.178282    8.242609    91.75739
  6       0.178957    8.332440    91.66756
  7       0.179107    8.340617    91.65938
  8       0.179127    8.340284    91.65972

Cholesky Ordering: D(MT) D(EUR6)
```

Malta



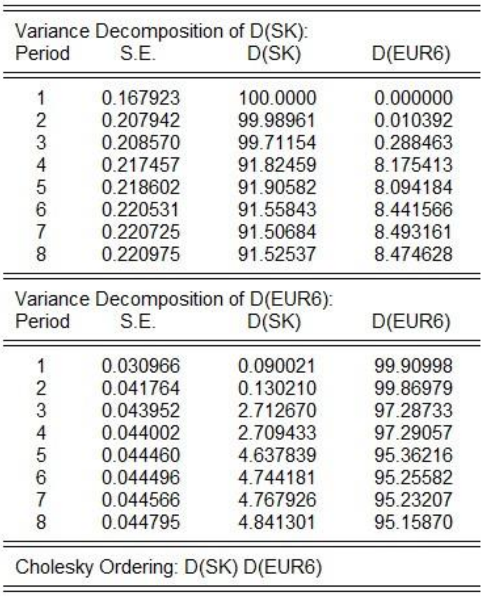
```
Variance Decomposition of D(MT):
Period      S.E.        D(MT)       D(EUR6)

  1       0.373814    100.0000    0.000000
  2       0.422346    99.89720    0.102800
  3       0.433717    99.79066    0.209340
  4       0.436626    99.77541    0.224594
  5       0.437382    99.77606    0.223942
  6       0.437568    99.77385    0.226147
  7       0.437622    99.77221    0.227791
  8       0.437636    99.77184    0.228163

Variance Decomposition of D(EUR6):
Period      S.E.        D(MT)       D(EUR6)

  1       0.031684    0.234761    99.76524
  2       0.041920    0.655409    99.34459
  3       0.043536    0.639209    99.36079
  4       0.043537    0.645149    99.35485
  5       0.043755    0.666769    99.33323
  6       0.043910    0.663003    99.33700
  7       0.043937    0.662216    99.33778
  8       0.043938    0.662912    99.33709

Cholesky Ordering: D(MT) D(EUR6)
```

Slovakia



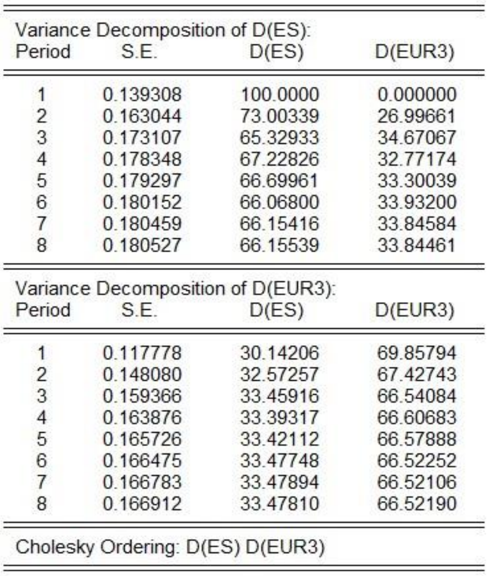
```
Variance Decomposition of D(SK):
Period      S.E.         D(SK)        D(EUR6)

   1      0.240575     100.0000     0.000000
   2      0.290846     87.61117     12.38883
   3      0.304955     80.20891     19.79109
   4      0.315891     76.57434     23.42566
   5      0.316212     76.60826     23.39174
   6      0.318935     76.71398     23.28602
   7      0.319335     76.75507     23.24493
   8      0.319387     76.75165     23.24835

Variance Decomposition of D(EUR6):
Period      S.E.         D(SK)        D(EUR6)

   1      0.105586     15.39727     84.60273
   2      0.150563     9.341167     90.65883
   3      0.172601     7.328677     92.67132
   4      0.184218     6.456317     93.54368
   5      0.187604     6.227099     93.77290
   6      0.188053     6.259346     93.74065
   7      0.188065     6.268597     93.73140
   8      0.188076     6.267950     93.73205

Cholesky Ordering: D(SK) D(EUR6)
```

Slovakia



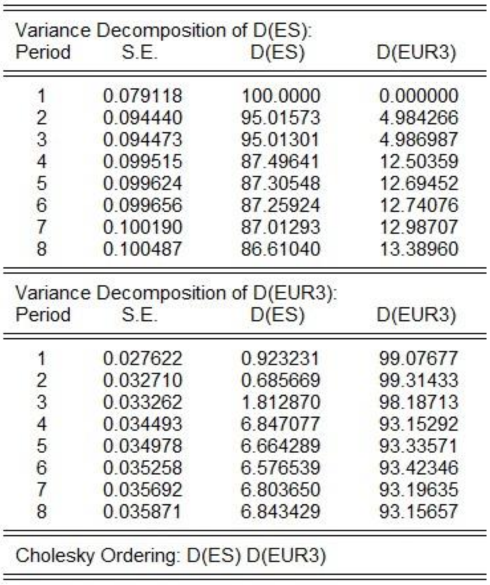
```
Variance Decomposition of D(SK):
Period      S.E.         D(SK)        D(EUR6)

   1      0.167923     100.0000     0.000000
   2      0.207942     99.98961     0.010392
   3      0.208570     99.71154     0.288463
   4      0.217457     91.82459     8.175413
   5      0.218602     91.90582     8.094184
   6      0.220531     91.55843     8.441566
   7      0.220725     91.50684     8.493161
   8      0.220975     91.52537     8.474628

Variance Decomposition of D(EUR6):
Period      S.E.         D(SK)        D(EUR6)

   1      0.030966     0.090021     99.90998
   2      0.041764     0.130210     99.86979
   3      0.043952     2.712670     97.28733
   4      0.044002     2.709433     97.29057
   5      0.044460     4.637839     95.36216
   6      0.044496     4.744181     95.25582
   7      0.044566     4.767926     95.23207
   8      0.044795     4.841301     95.15870

Cholesky Ordering: D(SK) D(EUR6)
```

Spain



```
Variance Decomposition of D(ES):
Period      S.E.         D(ES)        D(EUR3)

   1      0.139308     100.0000     0.000000
   2      0.163044     73.00339     26.99661
   3      0.173107     65.32933     34.67067
   4      0.178348     67.22826     32.77174
   5      0.179297     66.69961     33.30039
   6      0.180152     66.06800     33.93200
   7      0.180459     66.15416     33.84584
   8      0.180527     66.15539     33.84461

Variance Decomposition of D(EUR3):
Period      S.E.         D(ES)        D(EUR3)

   1      0.117778     30.14206     69.85794
   2      0.148080     32.57257     67.42743
   3      0.159366     33.45916     66.54084
   4      0.163876     33.39317     66.60683
   5      0.165726     33.42112     66.57888
   6      0.166475     33.47748     66.52252
   7      0.166783     33.47894     66.52106
   8      0.166912     33.47810     66.52190

Cholesky Ordering: D(ES) D(EUR3)
```

Spain

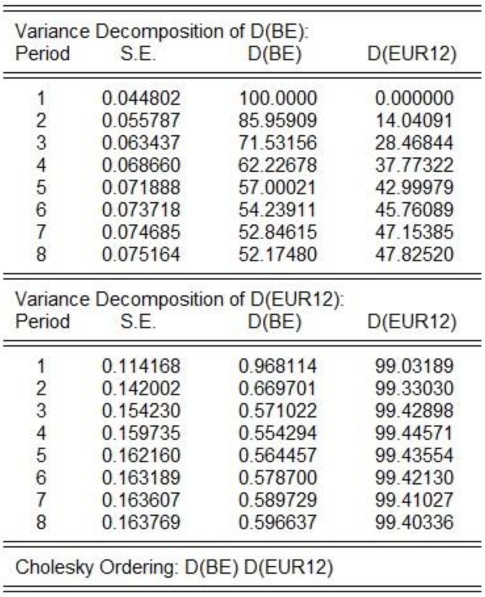
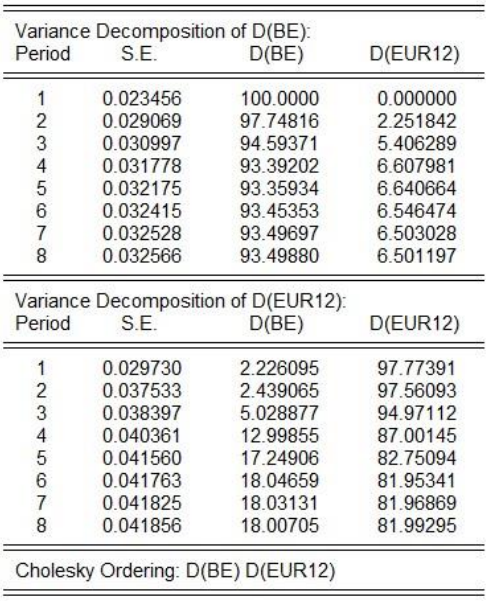
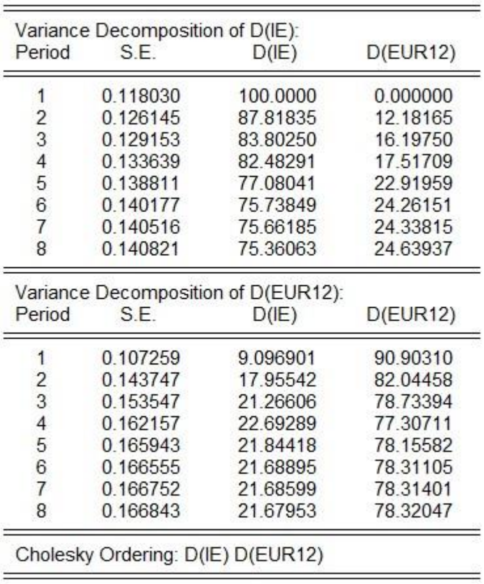
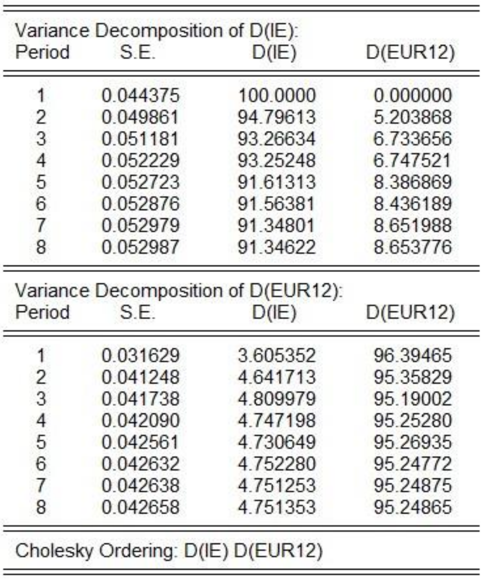


```
Variance Decomposition of D(ES):
Period      S.E.         D(ES)        D(EUR3)

   1      0.079118     100.0000     0.000000
   2      0.094440     95.01573     4.984266
   3      0.094473     95.01301     4.986987
   4      0.099515     87.49641     12.50359
   5      0.099624     87.30548     12.69452
   6      0.099656     87.25924     12.74076
   7      0.100190     87.01293     12.98707
   8      0.100487     86.61040     13.38960

Variance Decomposition of D(EUR3):
Period      S.E.         D(ES)        D(EUR3)

   1      0.027622     0.923231     99.07677
   2      0.032710     0.685669     99.31433
   3      0.033262     1.812870     98.18713
   4      0.034493     6.847077     93.15292
   5      0.034978     6.664289     93.33571
   6      0.035258     6.576539     93.42346
   7      0.035692     6.803650     93.19635
   8      0.035871     6.843429     93.15657

Cholesky Ordering: D(ES) D(EUR3)
```

Notes: The variables are coded as follows EUR3 = 3-month Euribor, EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, GR = Greece, IT = Italy, MT = Malta, SK = Slovakia and ES = Spain. ‘D’ refers to the first difference of the variable.

Source: Estimation by the author based on ECB data

Table 38: Variance decomposition table of households' cost of borrowing – Two period models

1st period	**2nd period**
Belgium	**Belgium**
	
Ireland	**Ireland**
	

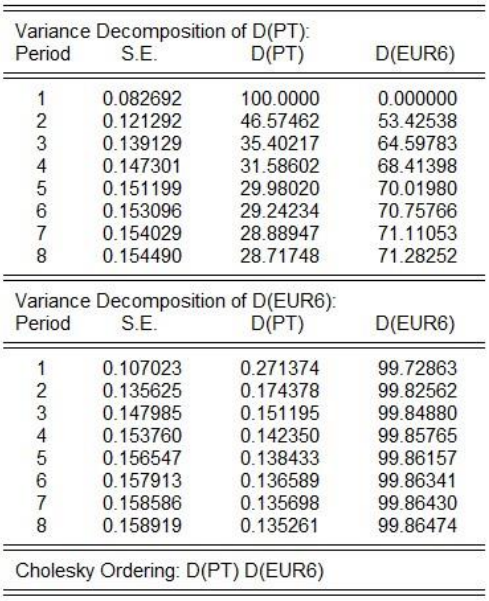
```
 Variance Decomposition of D(BE):
 Period        S.E.          D(BE)          D(EUR12)

    1       0.044802      100.0000       0.000000
    2       0.055787      85.95909       14.04091
    3       0.063437      71.53156       28.46844
    4       0.068660      62.22678       37.77322
    5       0.071888      57.00021       42.99979
    6       0.073718      54.23911       45.76089
    7       0.074685      52.84615       47.15385
    8       0.075164      52.17480       47.82520

 Variance Decomposition of D(EUR12):
 Period        S.E.          D(BE)          D(EUR12)

    1       0.114168      0.968114       99.03189
    2       0.142002      0.669701       99.33030
    3       0.154230      0.571022       99.42898
    4       0.159735      0.554294       99.44571
    5       0.162160      0.564457       99.43554
    6       0.163189      0.578700       99.42130
    7       0.163607      0.589729       99.41027
    8       0.163769      0.596637       99.40336

 Cholesky Ordering: D(BE) D(EUR12)
```

```
 Variance Decomposition of D(BE):
 Period        S.E.          D(BE)          D(EUR12)

    1       0.023456      100.0000       0.000000
    2       0.029069      97.74816       2.251842
    3       0.030997      94.59371       5.406289
    4       0.031778      93.39202       6.607981
    5       0.032175      93.35934       6.640664
    6       0.032415      93.45353       6.546474
    7       0.032528      93.49697       6.503028
    8       0.032566      93.49880       6.501197

 Variance Decomposition of D(EUR12):
 Period        S.E.          D(BE)          D(EUR12)

    1       0.029730      2.226095       97.77391
    2       0.037533      2.439065       97.56093
    3       0.038397      5.028877       94.97112
    4       0.040361      12.99855       87.00145
    5       0.041560      17.24906       82.75094
    6       0.041763      18.04659       81.95341
    7       0.041825      18.03131       81.96869
    8       0.041856      18.00705       81.99295

 Cholesky Ordering: D(BE) D(EUR12)
```

```
 Variance Decomposition of D(IE):
 Period        S.E.          D(IE)          D(EUR12)

    1       0.118030      100.0000       0.000000
    2       0.126145      87.81835       12.18165
    3       0.129153      83.80250       16.19750
    4       0.133639      82.48291       17.51709
    5       0.138811      77.08041       22.91959
    6       0.140177      75.73849       24.26151
    7       0.140516      75.66185       24.33815
    8       0.140821      75.36063       24.63937

 Variance Decomposition of D(EUR12):
 Period        S.E.          D(IE)          D(EUR12)

    1       0.107259      9.096901       90.90310
    2       0.143747      17.95542       82.04458
    3       0.153547      21.26606       78.73394
    4       0.162157      22.69289       77.30711
    5       0.165943      21.84418       78.15582
    6       0.166555      21.68895       78.31105
    7       0.166752      21.68599       78.31401
    8       0.166843      21.67953       78.32047

 Cholesky Ordering: D(IE) D(EUR12)
```

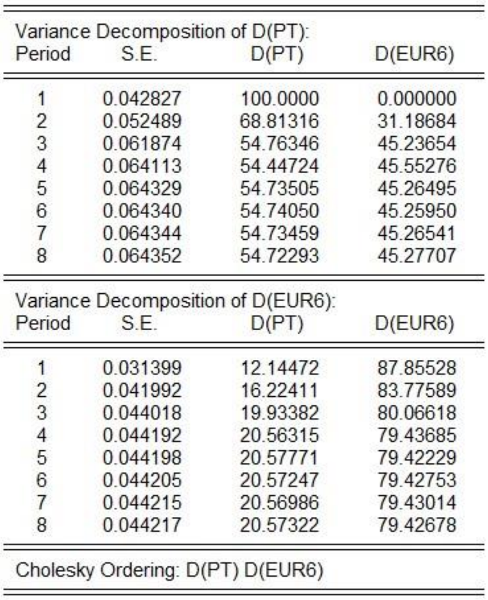
```
 Variance Decomposition of D(IE):
 Period        S.E.          D(IE)          D(EUR12)

    1       0.044375      100.0000       0.000000
    2       0.049861      94.79613       5.203868
    3       0.051181      93.26634       6.733656
    4       0.052229      93.25248       6.747521
    5       0.052723      91.61313       8.386869
    6       0.052876      91.56381       8.436189
    7       0.052979      91.34801       8.651988
    8       0.052987      91.34622       8.653776

 Variance Decomposition of D(EUR12):
 Period        S.E.          D(IE)          D(EUR12)

    1       0.031629      3.605352       96.39465
    2       0.041248      4.641713       95.35829
    3       0.041738      4.809979       95.19002
    4       0.042090      4.747198       95.25280
    5       0.042561      4.730649       95.26935
    6       0.042632      4.752280       95.24772
    7       0.042638      4.751253       95.24875
    8       0.042658      4.751353       95.24865

 Cholesky Ordering: D(IE) D(EUR12)
```

Portugal



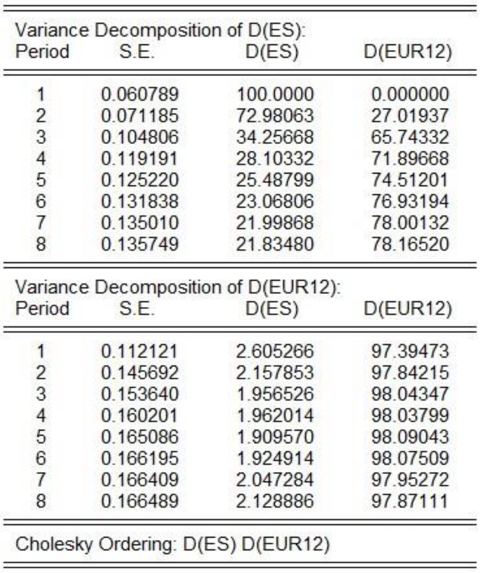
```
Variance Decomposition of D(PT):
Period      S.E.         D(PT)        D(EUR6)

  1       0.082692     100.0000     0.000000
  2       0.121292     46.57462     53.42538
  3       0.139129     35.40217     64.59783
  4       0.147301     31.58602     68.41398
  5       0.151199     29.98020     70.01980
  6       0.153096     29.24234     70.75766
  7       0.154029     28.88947     71.11053
  8       0.154490     28.71748     71.28252

Variance Decomposition of D(EUR6):
Period      S.E.         D(PT)        D(EUR6)

  1       0.107023     0.271374     99.72863
  2       0.135625     0.174378     99.82562
  3       0.147985     0.151195     99.84880
  4       0.153760     0.142350     99.85765
  5       0.156547     0.138433     99.86157
  6       0.157913     0.136589     99.86341
  7       0.158586     0.135698     99.86430
  8       0.158919     0.135261     99.86474

Cholesky Ordering: D(PT) D(EUR6)
```

Portugal



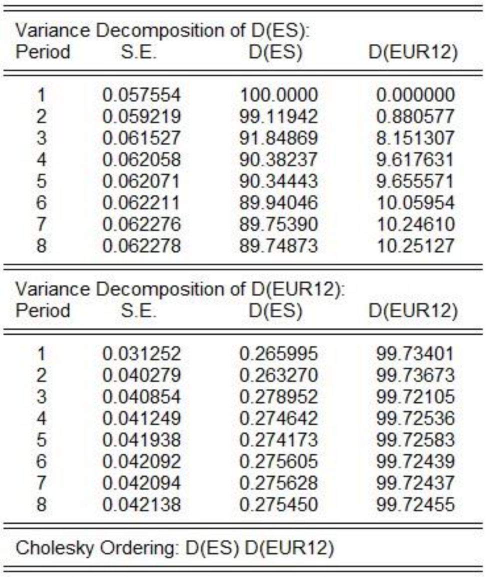
```
Variance Decomposition of D(PT):
Period      S.E.         D(PT)        D(EUR6)

  1       0.042827     100.0000     0.000000
  2       0.052489     68.81316     31.18684
  3       0.061874     54.76346     45.23654
  4       0.064113     54.44724     45.55276
  5       0.064329     54.73505     45.26495
  6       0.064340     54.74050     45.25950
  7       0.064344     54.73459     45.26541
  8       0.064352     54.72293     45.27707

Variance Decomposition of D(EUR6):
Period      S.E.         D(PT)        D(EUR6)

  1       0.031399     12.14472     87.85528
  2       0.041992     16.22411     83.77589
  3       0.044018     19.93382     80.06618
  4       0.044192     20.56315     79.43685
  5       0.044198     20.57771     79.42229
  6       0.044205     20.57247     79.42753
  7       0.044215     20.56986     79.43014
  8       0.044217     20.57322     79.42678

Cholesky Ordering: D(PT) D(EUR6)
```

Spain

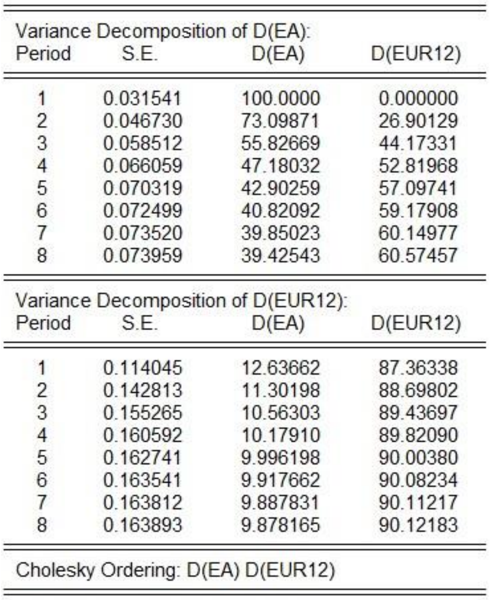
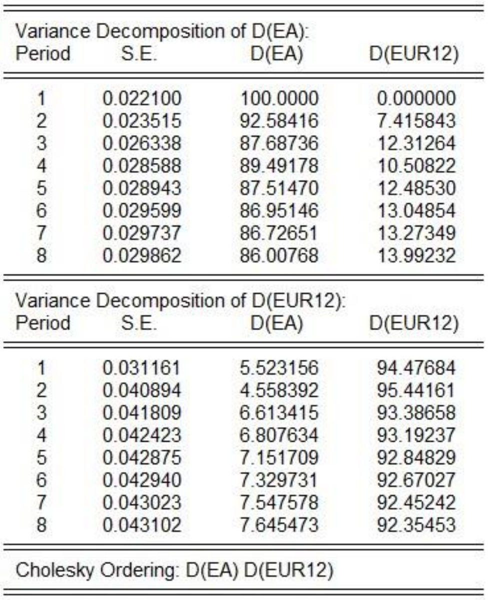


```
Variance Decomposition of D(ES):
Period      S.E.         D(ES)        D(EUR12)

  1       0.060789     100.0000     0.000000
  2       0.071185     72.98063     27.01937
  3       0.104806     34.25668     65.74332
  4       0.119191     28.10332     71.89668
  5       0.125220     25.48799     74.51201
  6       0.131838     23.06806     76.93194
  7       0.135010     21.99868     78.00132
  8       0.135749     21.83480     78.16520

Variance Decomposition of D(EUR12):
Period      S.E.         D(ES)        D(EUR12)

  1       0.112121     2.605266     97.39473
  2       0.145692     2.157853     97.84215
  3       0.153640     1.956526     98.04347
  4       0.160201     1.962014     98.03799
  5       0.165086     1.909570     98.09043
  6       0.166195     1.924914     98.07509
  7       0.166409     2.047284     97.95272
  8       0.166489     2.128886     97.87111

Cholesky Ordering: D(ES) D(EUR12)
```

Spain



```
Variance Decomposition of D(ES):
Period      S.E.         D(ES)        D(EUR12)

  1       0.057554     100.0000     0.000000
  2       0.059219     99.11942     0.880577
  3       0.061527     91.84869     8.151307
  4       0.062058     90.38237     9.617631
  5       0.062071     90.34443     9.655571
  6       0.062211     89.94046     10.05954
  7       0.062276     89.75390     10.24610
  8       0.062278     89.74873     10.25127

Variance Decomposition of D(EUR12):
Period      S.E.         D(ES)        D(EUR12)

  1       0.031252     0.265995     99.73401
  2       0.040279     0.263270     99.73673
  3       0.040854     0.278952     99.72105
  4       0.041249     0.274642     99.72536
  5       0.041938     0.274173     99.72583
  6       0.042092     0.275605     99.72439
  7       0.042094     0.275628     99.72437
  8       0.042138     0.275450     99.72455

Cholesky Ordering: D(ES) D(EUR12)
```

Euro Area	**Euro Area**
	

```
 Variance Decomposition of D(EA):
 Period      S.E.        D(EA)       D(EUR12)

   1      0.031541     100.0000     0.000000
   2      0.046730     73.09871     26.90129
   3      0.058512     55.82669     44.17331
   4      0.066059     47.18032     52.81968
   5      0.070319     42.90259     57.09741
   6      0.072499     40.82092     59.17908
   7      0.073520     39.85023     60.14977
   8      0.073959     39.42543     60.57457

 Variance Decomposition of D(EUR12):
 Period      S.E.        D(EA)       D(EUR12)

   1      0.114045     12.63662     87.36338
   2      0.142813     11.30198     88.69802
   3      0.155265     10.56303     89.43697
   4      0.160592     10.17910     89.82090
   5      0.162741     9.996198     90.00380
   6      0.163541     9.917662     90.08234
   7      0.163812     9.887831     90.11217
   8      0.163893     9.878165     90.12183

 Cholesky Ordering: D(EA) D(EUR12)
```

```
 Variance Decomposition of D(EA):
 Period      S.E.        D(EA)       D(EUR12)

   1      0.022100     100.0000     0.000000
   2      0.023515     92.58416     7.415843
   3      0.026338     87.68736     12.31264
   4      0.028588     89.49178     10.50822
   5      0.028943     87.51470     12.48530
   6      0.029599     86.95146     13.04854
   7      0.029737     86.72651     13.27349
   8      0.029862     86.00768     13.99232

 Variance Decomposition of D(EUR12):
 Period      S.E.        D(EA)       D(EUR12)

   1      0.031161     5.523156     94.47684
   2      0.040894     4.558392     95.44161
   3      0.041809     6.613415     93.38658
   4      0.042423     6.807634     93.19237
   5      0.042875     7.151709     92.84829
   6      0.042940     7.329731     92.67027
   7      0.043023     7.547578     92.45242
   8      0.043102     7.645473     92.35453

 Cholesky Ordering: D(EA) D(EUR12)
```

Notes: The variables are coded as follows EUR6 = 6-month Euribor, EUR12 = 12-month Euribor, BE = Belgium, IE = Ireland, LA = Latvia, LI = Lithuania, PT = Portugal, ES = Spain and EA = Euro Area. ‘D’ refers to the first difference of the variable. Response to Cholesky one S.D. innovations +/- 2 S.E.

Source: Estimation by the author based on ECB data