T.C.

TURKISH-GERMAN UNIVERSITY

INSTITUTE OF SOCIAL SCIENCES

DEPARTMENT OF INTERNATIONAL FINANCE

MACROECONOMIC ANALYSIS OF THE SHADOW INTEREST RATE IN THE EUROZONE AND USA

MASTER'S THESIS

Furkan KURTOĞLU

ADVISOR

Assoc. Prof. Dr. Semih Emre Çekin

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ABSTRACT

In this thesis, a comprehensive analysis is undertaken to understand the outcomes of the use of unconventional monetary policy of both the Federal Reserve (FED) and the European Central Bank (ECB) on the economy. Subsequent to the 2008 Global Financial Crisis, a shift transpired in the operational strategy of both central banks, characterized by unconventional monetary policies to stimulate economies, notably encompassing strategies like forward guidance and the implementation of quantitative easing.

By using these strategies, a clear difference emerged between conventional interest rates and so called shadow interest rates. The shadow interest rate provides a more precise gauge of the central banks' monetary policies.

In this study, a multi-faceted assessment is conducted, highlighting the distinctive reactions of various economic indicators, ranging from the real exchange rate and ten years government bond yields to the inflation rate and the GDP. These indicators are measured against the backdrop of both conventional interest rates and Shadow Interest Rates, making it possible to understand the reaction of the economy to various shocks.

Using shadow interest rates as outlined in Wu and Xia (2016) to analyze the monetary policy stance of the FED and ECB makes it easier for us to fully understand the monetary policy stance, as Shadow Interest Rate calculations take into account not only the market's funding rate but also the impact of unconventional monetary policy tools on the economy.

The results show that there are significant differences in the response of the economy when shadow rates are you used instead of conventional short term interest rates and highlight that it is more appropriate to use the proper metric for modeling monetary policy.

ÖZET

Bu tezde, hem ABD Merkez Bankası Federal Reserve'ın (FED) hem de Avrupa Merkez Bankası'nın (ECB) geleneksel olmayan para politikası kullanımının ekonomi üzerindeki sonuçları anlamak için kapsamlı bir analiz yapılmıştır. 2008 Küresel Mali Krizi'nin ardından, iki merkez bankasının da operasyonel stratejilerinde ekonomileri canlandırmaya yönelik, özellikle ileriye yönelik rehberlik ve niceliksel genişlemenin uygulanması gibi stratejileri kapsayan alışılmadık para politikalarıyla karakterize edilen bir değişiklik ortaya çıktı.

Bu stratejilerin kullanılmasıyla, geleneksel faiz oranları ile gölge faiz oranları olarak adlandırılan oranlar arasında belirgin bir fark ortaya çıktı. Gölge faiz oranı merkez bankalarının para politikalarının daha doğru ölçümünü sağlar.

Bu çalışmada reel döviz kurundan on yıllık devlet tahvili getirileri, enflasyon oranı, GSYİH gibi çeşitli ekonomik göstergelerin farklı tepkilerini ortaya koyan çok yönlü bir değerlendirme yapılmaktadır. Bu göstergeler hem geleneksel faiz oranları hem de gölge faiz oranları zemininde ölçülmekte ve ekonominin çeşitli şoklara verdiği tepkinin anlaşılmasına olanak sağlamaktadır.

FED ve ECB'nin para politikası duruşunu analiz etmek için Wu ve Xia (2016)'da ana hatlarıyla belirtildiği gibi gölge faiz oranlarının kullanılması, gölge faiz oranı hesaplamalarında yalnızca piyasanın finansmanını değil, aynı zamanda para politikası duruşunu da tam olarak anlamamızı kolaylaştırmaktadır.

Sonuçlar, geleneksel kısa vadeli faiz oranları yerine gölge faiz oranları kullanıldığında ekonominin tepkisinde önemli farklılıklar olduğunu göstermekte ve para politikasını modellemek için uygun ölçütü kullanmanın önemini vurgulamaktadır.

1. Introduction

Monetary policy is implemented in the form of contraction and expansion. When economies are in a recession, a central bank tries to stimulate the economy by implementing expansionary monetary policy. In contractionary monetary policy, a central bank try to cool and contract the economy. The main tool used by central banks in implementing these policies is the policy rate. A decrease in the policy interest rate indicates that an expansionary monetary policy is being followed, while an increase indicates that a contractionary monetary policy is being followed.

In certain situations, despite the central bank's implementation of an expansionary monetary policy, economies may still struggle to achieve a robust recovery. Consequently, central banks turn to the adoption of unconventional monetary policy tools. These unconventional measures come into play when conventional interest rate adjustments alone prove inadequate, or when unique economic conditions call for a distinct response. Unconventional monetary policy refers to strategies used by central banks when unconventional tools like adjusting interest rates become ineffective. These strategies include measures like purchasing assets (quantitative easing), setting negative interest rates, guiding future policy (forward guidance), and targeting specific parts of the economy to stimulate growth or combat deflation. Unconventional policies aim to influence borrowing, spending, and investment to revive economic activity during challenging times. When unconventional monetary policies are implemented, apart from the interest rate set by the central bank, another interest rate emerges in the market. This rate is called the Shadow Interest Rate.

Using Shadow Interest Rates to measure the economic stance of central banks can provide valuable insights into when conventional monetary policy tools become limited or less effective. There are several reasons why Shadow Interest Rates may be useful in assessing the economic stance of central banks:

1) Limited Room for Nominal Interest Rate Adjustments: When the official conventional interest rates are already at or near zero, central banks have little room to further lower rates to stimulate borrowing, spending, and investment. In such a scenario, Shadow Interest Rates allow central banks to estimate how much further they would ideally like to lower rates to provide additional stimulus if they could. 2) Quantitative Easing: Central banks often turn to unconventional monetary policies like quantitative easing (QE) when nominal interest rates are constrained. These policies involve purchasing financial assets to inject money into the economy. Estimating Shadow Interest Rates helps

central banks gauge the impact of these unconventional measures on borrowing costs and financial conditions. 3) Effective Lower Bound: The effective lower bound (ELB) is the point where nominal interest rates can no longer be lowered due to practical constraints. Shadow Interest Rates provide a way to assess how close the economy is to this ELB, which is important for central banks to determine the potential risks and need for further policy action. 4) Communication Strategy: Central banks communicate their monetary policy intentions to the public and financial markets. While they might not explicitly reveal Shadow Interest Rates, they can provide guidance on their thinking and approach when nominal rates are constrained. This can help manage expectations and provide a clearer picture of the central bank's policy stance. 5) Economic Modeling and Forecasting: Economists and researchers use economic models to simulate the effects of different policy actions. Shadow Interest Rates may provide a way to input more nuanced policy scenarios into these models, allowing for a more accurate analysis of potential outcomes. 6) Monitoring Financial Stability: Near-zero nominal interest rates can lead to investors seeking higher returns in riskier assets, potentially contributing to financial imbalances and bubbles. Estimating Shadow Interest Rates can help central banks assess the potential impact of their policies on asset prices and financial stability. 7) Comparative Analysis: Comparing the actual policy rate with the Shadow Interest Rate can help policymakers understand the gap between the current stance and what would be ideal given economic conditions. This comparison can guide decisions on policy adjustments and calibration.

Unconventional monetary policy tools have been widely utilized by central banks worldwide, especially following the 2008 Global Financial Crisis, to address economic challenges and support recovery efforts. These tools offer central banks increased flexibility to address deflation, low inflation, or persistently sluggish economic conditions.

However, it's essential to acknowledge that unconventional monetary policy measures may carry potential risks and side effects. As such, central banks carefully assess economic conditions and communicate their intentions when deploying these tools, seeking to achieve their objectives while managing potential consequences for financial markets and the overall economy.

The Shadow Interest Rate tool was introduced by various researchers in response to the difficulty of modeling monetary policy behavior during periods when the nominal interest rate is constrained by the zero lower bound. The tool is used by economists to estimate what the short-term interest rate would be in a hypothetical world where it is possible for central banks to set rates below zero. The

Shadow Interest Rate is calculated by estimating the parameters of a monetary policy rule and then simulating the model to calculate what the policy rate would be if it were not constrained by the zero lower bound. This tool allows economists to analyze the effects of monetary policy even when actual interest rates are at or near zero (Jones, Kulish, & Morley, 2021).

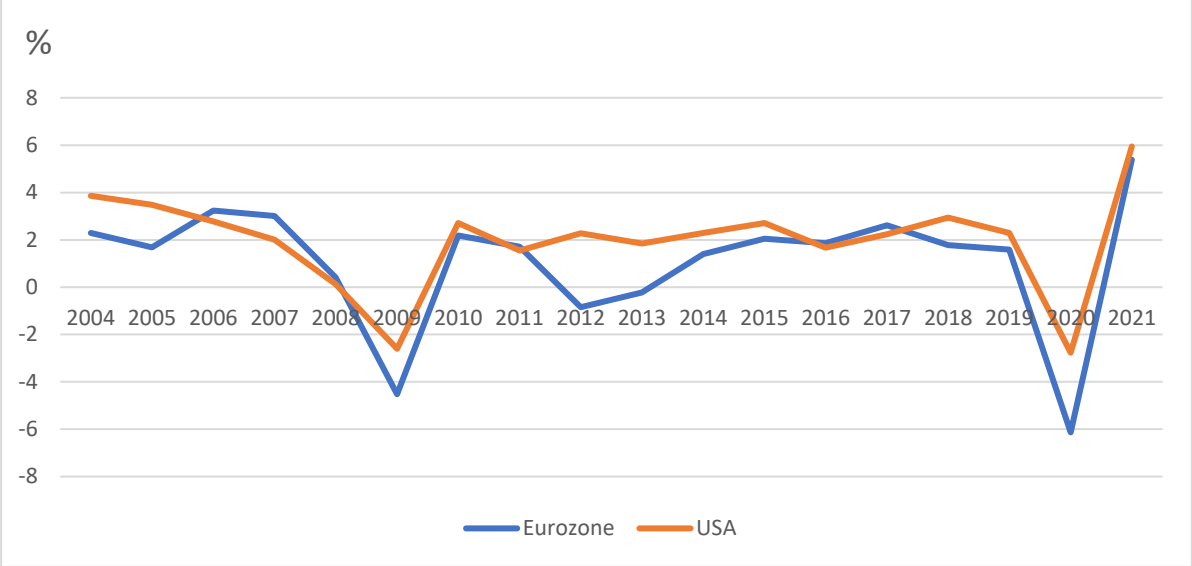
In this study, I aim to demonstrate that examining the Shadow Interest Rate yields different results in analyzing the economy's response to central banks' policies stance compared to the central bank's funding rate. An analysis is conducted on the period from 2004 to 2021, which is divided into three distinct parts. The first part focuses on the year 2004 to 2008, examining the events leading up to the 2008 Global Financial Crisis. The second part delves into the 2008 crisis itself, studying its effect and consequences on the economy. Following that, the thesis examines the Euro Crisis that followed after the 2008 Global Financial Crisis. The third part of the analysis covers the years from 2008 to 2018, studying the developments and trends during this period. Lastly, the thesis explores the period from 2019 to 2021, which includes the global epidemic and its impact on the USA and the Eurozone economies.

The thesis consists of seven sections. The first section is an introduction where information about unconventional monetary policy and the Shadow Interest Rate is provided. In the second section, the macroeconomic outlook of the USA and Eurozone regions between the analyzed dates, which will be subsequently analyzed, is evaluated. In the third section, the emergence of unconventional monetary policy and its implementation in the USA and Eurozone regions are explained. In the fourth section, a literature review is conducted where the theoretical and empirical evidence related to both the Shadow Interest Rate and conventional interest rate, including their advantages and limitations are examined. The fifth section describes the model and data used in the study, and the sixth chapter focuses on the findings where impulse response functions (IRF) are presented, showing how variables react when the Shadow Interest Rate and conventional interest rate are subject to shocks. In the seventh chapter, the findings are discussed, and shows the conclusion.

2. Macroeconomic Framework in The Eurozone and USA Between 2004-2021

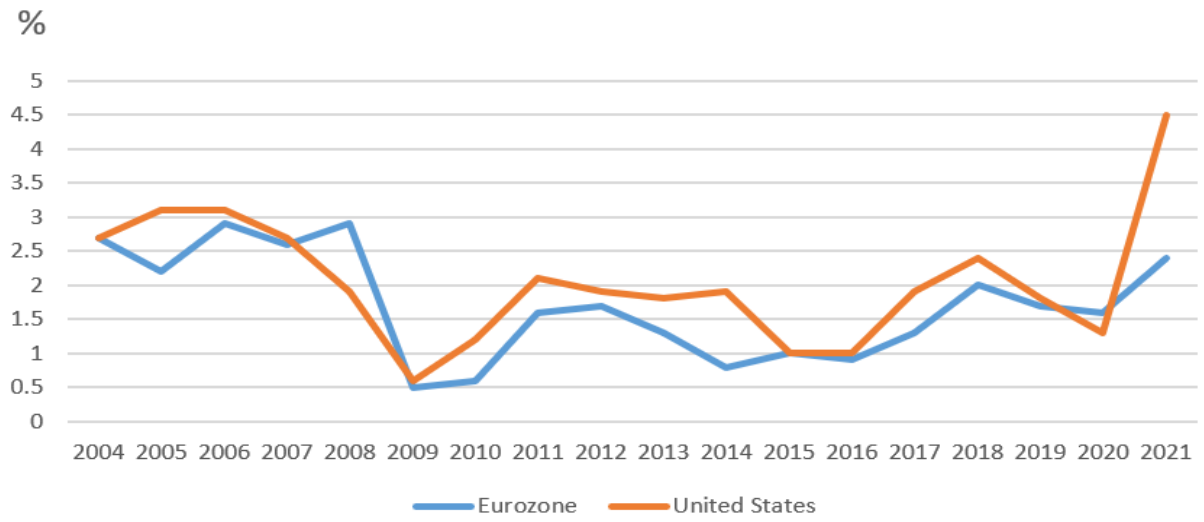
In this section the macroeconomic dynamics of the US and of the Euro area briefly outlined for the period 2004-2021. The aim is to provide an economic understanding of the period when unconventional policies were implemented, the difference between shadow interest rates and short-term policy rates and why this difference and its implications are studies in detail in this thesis.

Graph 1. Growth Rate of Real GDP For the USA and the Eurozone



Source: World Bank Annual Growth Rates

Graph 2. Inflation rate of the USA and Eurozone



Source: World Bank Annual Inflation Rates as measured by CPI

During the period 2004-2008, the Eurozone's macroeconomic indicators witnessed a notable phase of relative stability, as reflected in the trajectory of its key economic metrics. The Eurozone's growth rate (Graph 1) during this interval was relatively stable, fluctuating between 1.6% and 3%. Simultaneously, the Eurozone's inflation rates had an average value of approximately 2.5%. (World Bank Inflation and Growth Rate, 2022). When we look at the growth and inflation data of the USA between 2004-2007, we see a positive growth rate and low inflation rate (World Bank Data Base, 2022). The genesis of the 2008 Global Financial Crisis can be traced back to the seismic collapse of the United States housing markets. The factor that precipitated this worldwide financial turmoil was the implosion of the housing bubble that had been inflating over the preceding years. The heart of the crisis lay in the abrupt deflation of this bubble, setting in motion a chain of events that reverberated globally (Helleiner, 2011). The repercussions of the 2008 Global Financial Crisis were manifested in the destabilization of financial institutions, underscoring the systemic vulnerabilities that had permeated global finance. The initial tremors of this event were discernible in the months of May and June in 2007, as a series of hedge funds collapsed. Despite the presence of reassurances aimed at alleviating market concerns, the crisis steadily gained momentum, reaching a critical threshold by March of 2008 (Helleiner, 2011). The bankruptcy of Lehman Brothers marks the beginning of the Global Financial Crisis because of globalization in financial markets. The crisis spread all around the

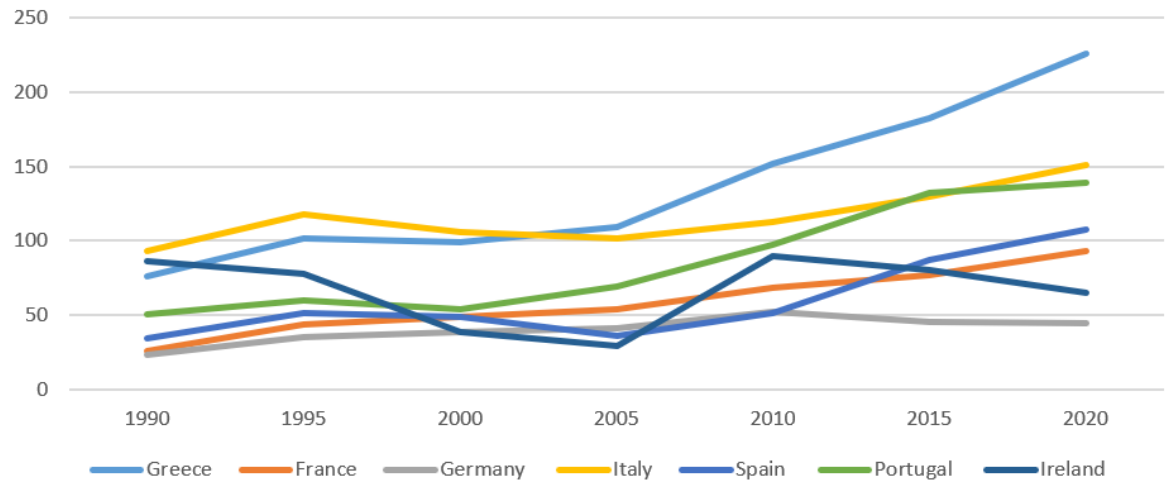
world, causing a recession in many countries. It especially caused the US economy and the Eurozone economy to contract for two consecutive years, leading to a high unemployment rate. In 2008, the growth rate of the United States was recorded at -0.13%, followed by a more severe contraction of -2.53% in 2009. During the same period, the Eurozone observed a growth rate of 0.4% in 2008, which was followed by a substantial decline of -4.5% in 2009.

By the year 2010 both the Eurozone and the United States seemingly recovered, achieving growth rates around 2%. However, real GDP in the United States remained significantly below its pre-crisis trend level, i.e., potential GDP, while the Eurozone experienced a debt crisis (as explained in the next subsection). These developments also explain why unconventional policies were implemented.

2.1. Euro Crisis

During the 1990s, both the Eurozone and the USA exhibited comparable patterns in their debt dynamics, as evidenced by their gross public debt-to-GDP ratios hovering around 60% for the Eurozone countries and approximately 70% for the United States. As the decade progressed, these ratios experienced a decline, signaling improved fiscal positions by the end of the 1990s. However, the positive trajectory did not persist, as both the United States and the Eurozone witnessed a reversal in their debt-to-GDP ratios, returning to levels reminiscent of the mid-1990s just prior to the 2008 Global Financial Crisis. The crisis period saw a rapid increase in the ratio of public debt to GDP, with the degree of increase being more pronounced in the United States compared to the Eurozone (Lane, 2012).

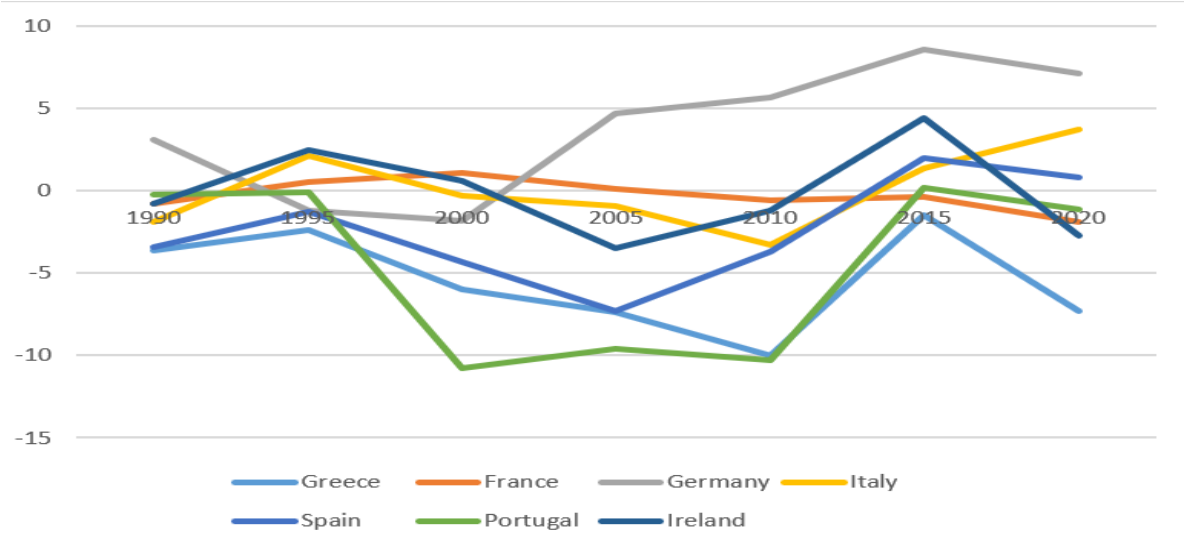
Graph 3. The Ratio of Public Debt to GDP



Source: IMF Public Debt Database the Ratio of Public Debt to GDP

Graph 3 shows the ratio of public debt to the national income of seven countries between 1990 and 2020.

Graph 4. The Ratio of Current Account Balance to GDP



Source: IMF's World Economic Outlook database the Ratio of Current Account Balance to GDP

From Graph 4, it is apparent that countries such as Portugal and Greece exhibited larger current account deficits in the lead-up to the Eurozone crisis.

The effects of the 2008 Global Financial Crisis on the Eurozone became crucial due to the crisis being not fully resolved although the Eurozone countries made serious efforts to solve the problems brought by the 2008 Global Financial Crisis. The ECB has the authority to manage monetary policies, but fiscal policy is managed differently by each country. These countries can follow different fiscal policies from each other, and Northern European countries had an economic model based on high-tech exports, which enabled them to achieve high-income levels. In contrast, southern European countries had a demand-driven growth strategy, and the Eurozone reached an uneasy balance between Southern Europe's demand-led growth strategy and Northern Europe's export and surplus. Southern European countries adopted a low labor cost strategy, which caused a low demand for the economy. To address this situation, they started borrowing capital from other countries, which eventually led to the Debt Crisis in Europe (Bakir, Bahtiyar, & Isik, 2016).

In late 2009, the deficit/GDP ratios of some members of the Euro Area increased more than expected. For example, fiscal revenues in Ireland and Spain fell much faster than GDP. There was a significant decrease in tax revenues. This is because tax revenues are sensitive to construction activities and declines in asset prices (Lane, 2012).

The origins of the Debt Crisis can be traced back to its initial outbreak in Greece. Subsequently, the crisis gradually extended its reach to several other nations across Europe. The triggering factor behind this crisis stemmed from the economic stagnation generated by the 2008 Global Financial Crisis, which in turn led to a substantial reduction in tax revenues for many countries. Consequently, there was a marked escalation in the levels of public debt within Southern European nations.

In an attempt to avert defaulting on its debt, Greece received financial assistance from core countries and the International Monetary Fund (IMF) in May of 2010. Nevertheless, despite these efforts, the crisis propagated to additional countries, notably including Ireland, Spain, Portugal, and Italy. This expansion of the crisis was influenced by interconnected economic factors and fiscal vulnerabilities present within these nations (Aygül, 2014).

2.2. Inflation Rates in the USA and Eurozone After the 2008 Global Crisis

During the interval spanning from the aftermath of the 2008 Global Financial Crisis to the year 2020, inflation rates exhibited a tendency to maintain a state of stability, remaining near to their predefined targets. This trend was particularly evident in both the Eurozone and the United States, where inflation rates hovered at approximately 2% annum throughout this duration.

In the wake of the 2008 Global Financial Crisis, there was a period in 2011 when inflation rates surpassed the 3% mark in both the Eurozone and the United States. However, subsequent to this occurrence, spanning from 2011 to 2020, these rates demonstrated a pattern of fluctuation contained within the range of 0 to 2%. This phase of relative stability underscored the concerted efforts aimed at maintaining inflation rates within target ranges amid the complex economic landscape (Federalreserve.gov, 2020).

The FED targets an inflation rate of 2% to pursue maximum employment and price stability. However, inflation has been consistently below the FED's target of 2% for many years. The FED reports that when inflation is too low, it can slow down the economy and discourage households and businesses from spending. On the other hand, when inflation is high, households and companies may lose income due to the higher cost of goods and services. To achieve its target inflation rate, the FED uses various monetary policy tools, such as adjusting interest rates and implementing quantitative easing (Federalreserve.gov, 2020).

The emergence of the Covid-19 pandemic in 2020 had a profound impact on global economies, leading to widespread income losses for individuals. To address the crisis, central banks across the globe adopted a loose monetary policy approach aimed at mitigating these income losses and fostering economic stability. In particular, the FED responded by implementing a series of interest rate reductions during its meetings held on March 3, 2020, and March 15, 2020. The Federal Funds Rate, which had previously ranged from 2% to 2.50%, was promptly adjusted to a new target range of 0% to 0.25%. This policy maneuver was undertaken with the objective of reducing the cost of borrowing, stimulating consumer spending, and incentivizing increased investment within the economy. By taking such measures, the FED aimed to provide support during the exceptional economic challenges posed by the pandemic and encourage a quicker recovery (Ihrig, Weinbach, & Wolla, 2020).

2.3. Growth Rate in the USA and Eurozone After the 2008 Global Financial Crisis

Following the aftermath of the 2008 Global Financial Crisis, the United States embarked on a path of recovery, maintaining positive growth rates until the onset of the Covid-19 Crisis. In contrast, the Eurozone faced a recession after the 2008 crisis, compounded by the challenges of the previously mentioned Debt Crisis. This led to contractions in the Eurozone economies in the years 2012 and 2013. Subsequent to this period, the Eurozone managed to maintain positive growth rates until the outbreak of the Covid-19 Crisis.

With the emergence of the global Covid-19 pandemic, economies worldwide experienced successive shutdowns, resulting in the halt of both demand and production. Consequently, economic growth rates across the globe plummeted into negative territory. In 2020, a year marked by the most severe impacts of the pandemic, the US economy contracted by 3.4%, while the Eurozone economy contracted by a more substantial 6.3% (as per the World Economic Outlook, 2021).

As the global pandemic's pace abated in 2021, economies gradually regained traction. During this period, the US economy expanded by 6%, and the Eurozone exhibited growth of 5%, indicating signs of recovery and adaptation in the face of the unprecedented challenges posed by the pandemic (World Economic Outlook, 2021).

3. Development and Implementation of Unconventional Monetary Policy

3.1. Unconventional Monetary Policy in Japan

It is worth mentioning the experience of the BOJ with unconventional monetary policy measures. The 1990 decade is also called “lost decade” for Japan’s economy, with low growth and low inflation rates. The long period of economic stagnation resulted from a combination of negative factors, most notably the precipitous decline in asset prices. Triggered by the burst of the asset price bubble, the Japanese economy's trajectory was profoundly altered, ushering in an era of prolonged stagnation characterized by persistently subdued growth and demand. (Ueada,2011; Hayashi, F., & Prescott, E. C. 2002)

The BOJ, in a bid to mitigate the adverse consequences of this economic malaise, had already embarked on a trajectory of proactive measures, notably decreasing overnight interest rate to levels below 0.5% during the summer of 1995. This marked a stark deviation from the previous high of

8.6% recorded in 1991, signaling the central bank's commitment to deploying conventional measures to stimulate economic activity. However, despite these efforts, the economy experienced a sharp credit crunch during the years 1997-1998, underscoring the limitations of conventional policy tools in countering deflationary pressures and weakened credit intermediation channels (Ueda, 2011).

This caused the BOJ to implement a series of unconventional policies, including large-scale asset purchases and forward guidance, aimed at reviving inflationary expectations, and revitalizing the credit flow mechanism. As such, the BOJ's experience stands as a case study in the application of unconventional measures.

The BOJ continued its monetary policy efforts by further reducing the overnight interest rate to nearly zero by early 1999. In the second half of 1998, Japan experienced negative inflation rates, and since then, the inflation rates have struggled to stay in positive territory for an extended period (Ueda, 2011). These economic circumstances led to what is commonly referred to as “liquidity trap” in the Japanese economy. In a liquidity trap, monetary policy loses its effectiveness as nominal interest rates approach zero, and the central bank’s ability to stimulate borrowing and spending through conventional means diminishes significantly. This compelled the BOJ to explore unconventional monetary policy tools, such as quantitative easing and forward guidance, to combat the persistently sluggish economic conditions (see e.g., Bernanke et al., 2004).

The BOJ’s experience with unconventional monetary policy provides valuable insights into the challenges faced by central banks in stimulating economic activity during times of prolonged stagnation and low inflation rates. The BOJ’s initiative of implementing unconventional monetary policy in the late 1990s made it one of the first major central banks to do so. The central tool of this unconventional approach is quantitative easing, which involves expanding the money supply and purchasing substantial quantities of government bonds and other securities to lower long-term interest rates. The BOJ's quantitative easing program is composed of three main components. Firstly, it committed to maintaining a zero-interest rate until deflation subsides. Secondly, it significantly increased the bank's balance sheet by changing the composition of its assets. Lastly, the BOJ engaged in direct purchases of longer-term Japanese government bonds.

The BOJ embarked upon the inception of its quantitative easing policy in March 2001, an initiative that persisted until March 2006. During this time, Japan faced various challenges, including slow economic growth, persistent deflation, and the ongoing issue of underperforming bank loans. The

genesis of this policy was characterized by the BOJ's effort to augment the balance of outstanding current accounts at the central bank, manifesting as an initial increase from 4 trillion Yen to 5 trillion Yen.

One important aspect of the BOJ's comprehensive strategy was the gradual increase in its efforts by buying more long-term government bonds over time. The commencement of this endeavor was marked by an initial allocation of 400 billion Yen, which served as a seminal step toward the BOJ's ambitious objective. The commitment to increase the bond purchase volume has emerged steadily as the BOJ gradually expanded its buying activities. The strategy was designed to address a complex set of economic challenges, including slow growth, persistent deflation, and the widespread issue of low credit quality in the banking sector.

The BOJ's quantitative easing policy during this time illustrates the efforts of central banks in dealing with economic challenges. This approach sought to strike a delicate balance between promoting economic growth, countering deflation, and revitalizing credit mechanisms in the banking sector (Rogers, Scotti, & Wright, 2014).

Having implemented unconventional policies in the 1990s, in response to the 2008 Global Financial Crisis, the BOJ reintroduced its quantitative easing policy in October 2010, and it has maintained it ever since. As part of a comprehensive monetary policy that included a virtually zero-interest rate policy, the BOJ announced another asset purchase program in October 2010. The asset purchase program aimed to reduce maturity and risk premiums by purchasing various assets, such as government bonds, corporate bonds, real estate investment trusts, and exchange-traded funds (Rogers, Scotti, & Wright, 2014).

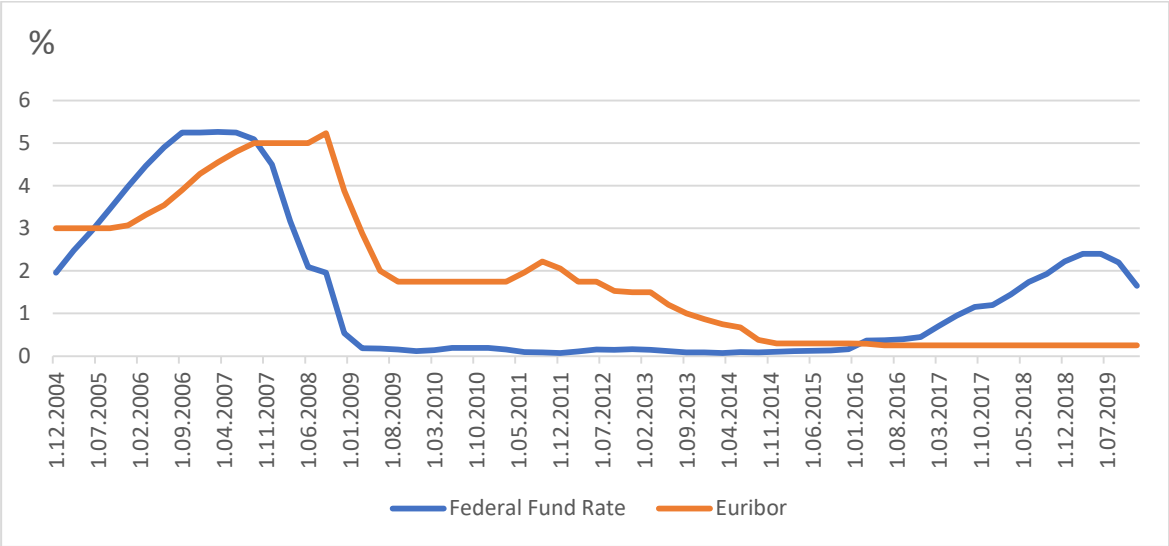
The experience of Japan with unconventional policies is important for our understanding of the policies that were implemented by the FED and the ECB in response to the 2008 financial crisis, as it likely influenced policy makers (Bernanke, B. 2017).

3.2. Developments in Monetary Policy Between 2004-2021 in the Eurozone and USA

Between 2004 and 2021, monetary policies in Europe and the United States underwent various changes in response to different periods and crises. Starting with the impact of the 2008 Global Financial Crisis, both FED in the United States and the ECB similarly lowered interest rates and adopted expansionary monetary policies. However, in the 2015, the United States began to tighten its

monetary policy and gradually raising interest rates. In contrast, the ECB continued to support the Eurozone's economy by maintaining negative (shadow) interest rates and ongoing asset purchases for an extended period. Additionally, following the COVID-19 pandemic, both regions implemented significant stimulus measures and liquidity injections to promote economic recovery. Consequently, during this period, monetary policies in the United States and Europe exhibited different approaches that adapted to crises and economic conditions.

Graph 5. Interest Rates of The USA and Eurozone



Source: FED.St Louis Interest Rates

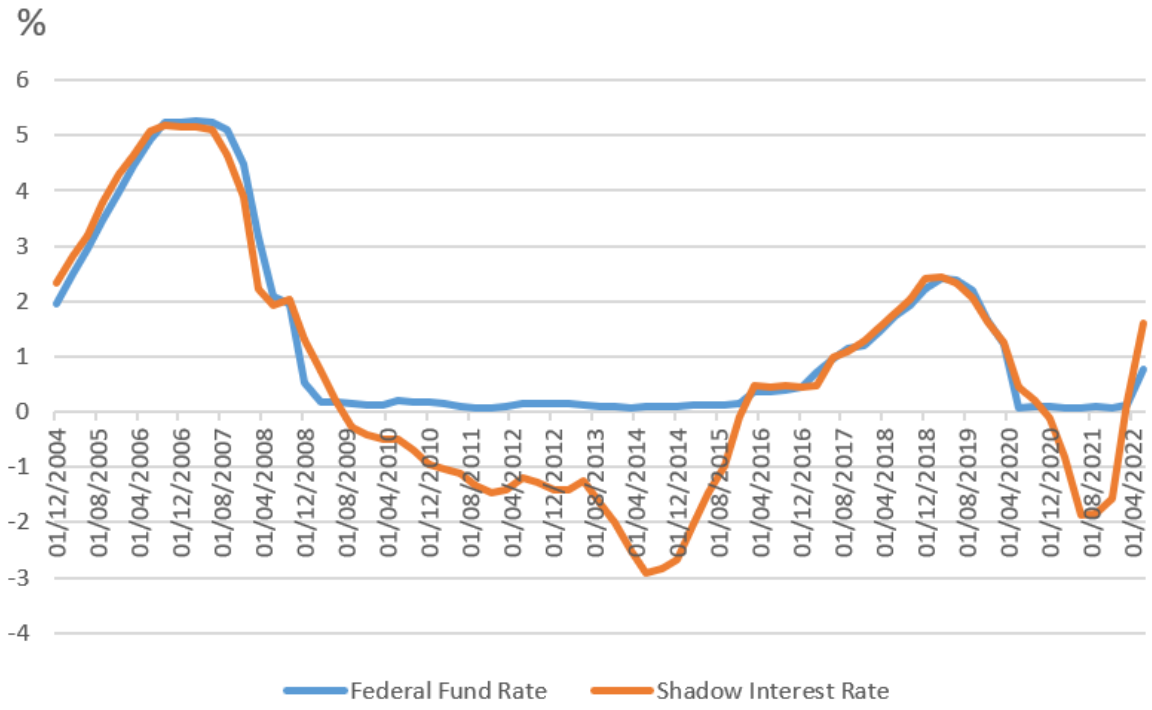
It can be argued that until 2008, most central banks pursued conventional monetary policy, where the main policy tool was the short-term interest rate. The 2008 Global Financial Crisis highlighted the limitations of conventional monetary policy, which primarily relied on adjusting short-term interest rates to influence economic conditions. As interest rates reached near-zero levels following the crisis, central banks realized that conventional measures alone were insufficient to stimulate economies and address the challenges at hand.

In response, central banks around the world adopted unconventional monetary policy measures to provide additional support and stimulate economic growth. These unconventional policies involved the use of new tools and strategies, such as large-scale asset purchases (Quantitative Easing), forward guidance, and targeting lending programs. The goal was to lower long-term interest rates, increase liquidity in financial markets, and encourage borrowing and spending.

The distinction between conventional and unconventional monetary policy is crucial. In conventional circumstances, central banks primarily rely on adjusting short-term interest rates to influence economic conditions. However, when short-term interest rates reach near-zero levels, conventional policy tools become less effective. Unconventional policies like quantitative easing shift the focus on the size of the central bank's balance sheet and the quantity of money in circulation, rather than solely relying on interest rates adjustment. This unconventional approach allows central banks to continue stimulating the economy even when conventional policy tools are limited. By directly affecting long-term interest rates and providing liquidity to financial markets, quantitative easing supports credit availability, promotes economic activity, and helps address deflationary pressures during periods of economic downturns (Bowdler & Radia, 2012).

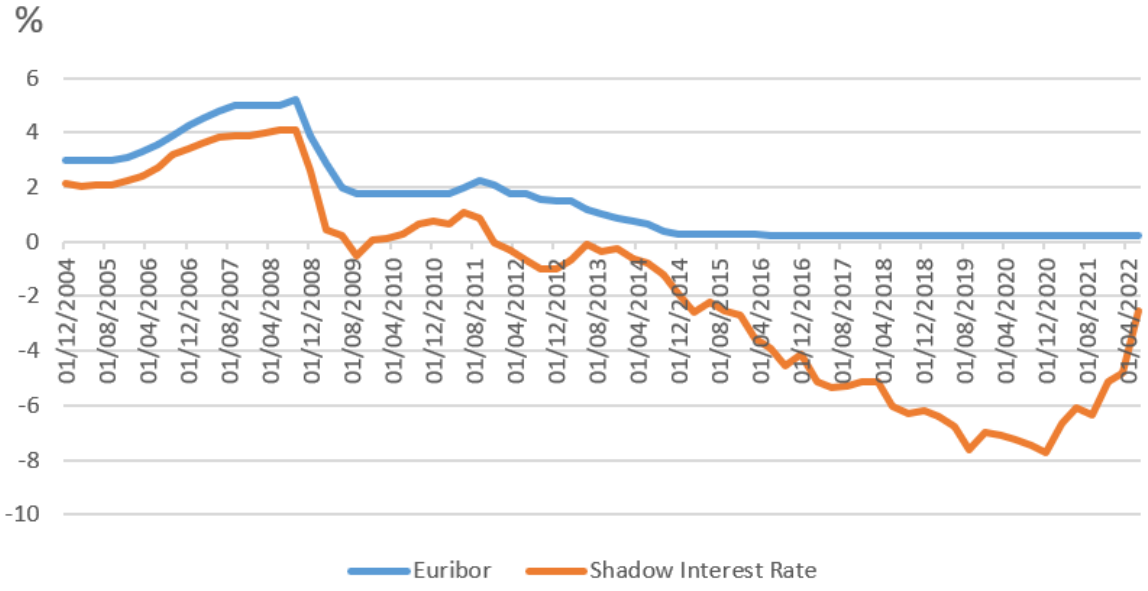
Between November 2008 and 2013, the FED implemented a series of large-scale asset purchase programs. During this period, the FED purchased over 3 trillion in bonds as part of its efforts to provide additional monetary stimulus and support the economy (Bauer & Neely, 2014). The asset purchase programs undertaken by the FED were accompanied by clear explanations and communication from the FOMC which is the monetary policy-making body within the FED. The FOMC regularly communicated its intentions and the rationale behind the asset purchases to ensure transparency and provide guidance to financial markets and the public.

Graph 6. Federal Funds Rate and Shadow Interest Rate in the USA



Source: IMF, Wu and Xia (2016)

Graph 7. Euribor and Shadow Interest Rate in The Eurozone

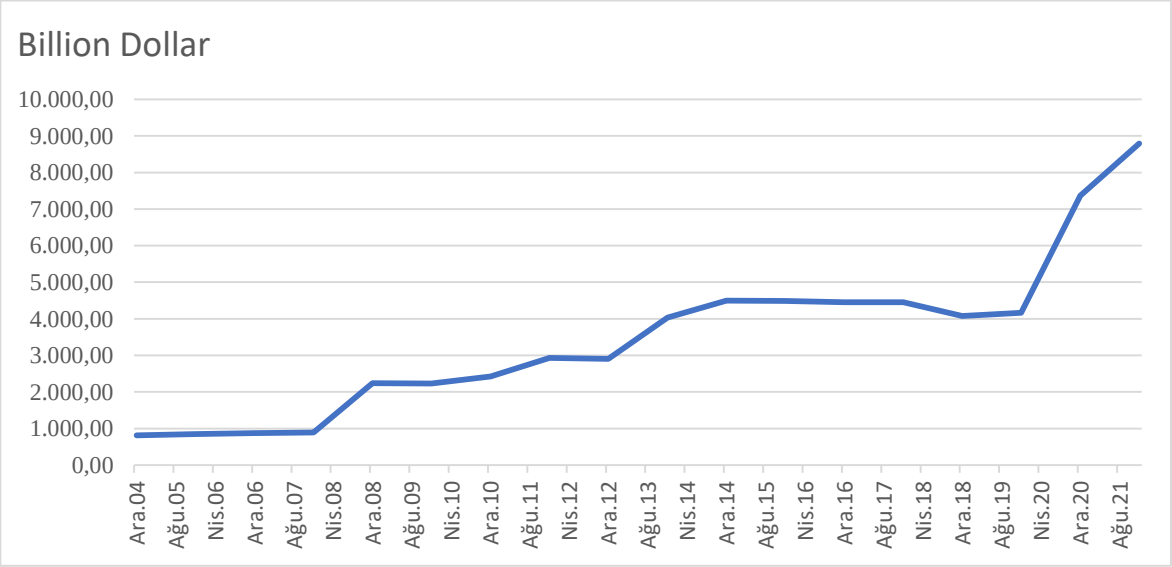


Source: Source: IMF, Wu and Xia (2016)

As can be seen in graphs 6 and 7, before the 2008 Global Financial Crisis, Shadow Interest Rates closely followed short term policy rates. However, the adoption of unconventional monetary policies like quantitative easing and forward guidance post-crisis led to a significant divergence between these rates. These policies expanded central bank balance sheets, reducing long-term interest rates and consequently lowering the Shadow Interest Rate.

In the USA, the Federal Funds Rate and Shadow Interest Rate converged later, while in the Eurozone, this convergence happened in 2013. However, in the Eurozone, the Shadow Interest Rate and Euribor continued to diverge after 2013. The Euro Debt Crisis worsened the economic situation, leading to a prolonged recession and magnifying the impact of unconventional policies. The Covid-19 pandemic further widened the gap between conventional interest rates and Shadow Interest Rates as central banks executed extensive asset purchases to bolster their economies.

Graph 8. Total Assets of FED



Source: FED.St Louis Total Assets of FED

Although the FED's balance sheets remained stable until the 2008 Global Financial Crisis, the increase that occurred after the crisis is clearly visible in the chart above.

As shown in the chart above, the FED consistently increased its asset purchases until 2013, after which it began the tapering process. FED reported that it would reduce the rate of asset purchases and

eventually tighten monetary policy, resulting in a rate of $45 billion and agency mortgage-backed securities at a rate of $40 billion per month (Federal Reserve issues FOMC statement, 2013).

The Euro Crisis in Europe resulted in an economic recession, but monetary expansion continued to revive the European economy. Due to the Euro Crisis, many European countries experienced negative growth rates. However, low inflation rates enabled the ECB to implement a low-interest rate policy. The ECB reduced the nominal interest rates to negative rates.

3.3. ECB Monetary Policy After the Beginning of the Euro Crisis

The Euro Crisis posed significant challenges to the European economy and necessitated the implementation of unconventional monetary policy by the European ECB. Conventional monetary policy measures alone proved insufficient to address the complex issues arising from the crisis, and unconventional tools were employed to stabilize the Eurozone economies. Here are the main unconventional policy tools implemented by the ECB:

Covered Bond Purchase Programme (CBPP): The CBPP involved the purchase of covered bonds issued by European banks. Covered bonds are a type of debt instrument backed by a pool of high-quality assets, providing an extra layer of security for investors. By buying these bonds, the ECB aimed to inject liquidity into the banking system and encourage lending to households and businesses.

Fixed-Rate Full Allotment Procedure for Longer-Term Refinancing Operations (LTRO): The LTRO involved the ECB providing long-term loans to European banks at a fixed interest rate. The full allotment procedure meant that banks could borrow as much as they needed against eligible collateral. This measure aimed to enhance banks' access to funding, stabilize the financial system, and promote lending to support economic activity.

Outright Monetary Transactions (OMT): The OMT program was announced in 2012 as a mechanism to purchase government bonds of distressed Eurozone countries. The objective was to reduce sovereign borrowing costs and alleviate market pressures on these countries. The mere announcement of the program had a calming effect on financial markets, as it signified the ECB's commitment to safeguard the euro.

Securities Market Programme (SMP): The SMP was launched in 2010 to address the rising yields on government bonds of some Eurozone countries. Under this program, the ECB purchased government bonds in the secondary market to help stabilize yields and restore market confidence.

These unconventional policy tools were part of the ECB's broader efforts to provide liquidity to the financial system, support credit provision, and tackle the underlying issues affecting the Eurozone during the crisis. The ECB's implementation of unconventional measures demonstrated its commitment to preserving the stability of the Eurozone and ensuring the functioning of the monetary union in challenging times (Pronobis, 2014).

The most significant action taken by the ECB was the implementation of the "Fixed-Rate Full-Allotment Procedure for Longer-Term Refinancing Operations" (LTRO). At the beginning of December 2011, the ECB's balance sheet stood at around 2.4 trillion Euros, but by March 2012, it had exceeded 3 trillion Euros (Belke, 2012). This program aimed to provide emergency liquidity to the European banking system through three-year refinancing operations. Additionally, the ECB also took another measure, which involved purchasing certain financial securities, especially government-owned securities (Pronobis, 2014).

These operations aimed to transmit monetary policy impulses to the larger economy. Another aim of the ECB was to reduce the cost of borrowing as countries like Greece, Italy, Portugal, and Spain were over-indebted. However, the financial impact of this policy was limited, as, by the end of 2012, the ECB had purchased 100 billion Euros of secured bonds and 220 billion dollars of government bonds, accounting for 3.5% of GDP. Compared to other central banks, the ECB’s unconventional monetary policy appears to be moderate (Pronobis, 2014).

3.4. Monetary Policy in the Covid Crisis

Since the time frame analyzed in this thesis encompasses the Covid period as well, it is worth looking into monetary policy measures following the Covid Crisis. The pandemic that emerged in China in 2019 caused central banks around the world to adjust their monetary policies in response to the impact on economic activity. Both the Eurozone and the USA experienced a sharp decline in economic activity due to lockdown measures and restrictions which were imposed to control the spread of the virus, various measures were implemented, including lockdowns and restrictions on businesses and social activities. Many businesses, especially those in sectors such as travel, hospitality, and retail, experienced closures, or reduced operations, resulting in a contraction in GDP. To mitigate the economic impact, central banks injected liquidity into the economies, as it was the most severe blow to the world economy since the Great Depression. Central banks responded to the crisis on an unprecedented scale. The FED acted swiftly and utilized all available tools, both conventional and

unconventional. Some of the measures implemented by the FED included reducing interest rates to the range of 0 to 0.25%. Additionally, the FED offered forward guidance, purchasing treasury securities and repurchasing agreement operations, and provided liquidity and funding to support money market functioning (Clarida, Duygan-Bump, & Scotti, 2021).

In March 2020, the ECB announced a series of measures. First, it decided to apply significantly more favorable terms to all TLRTO III transactions between June 2020 and June 2021. The ECB aimed to encourage lending, particularly to small and medium-sized intermediaries, by implementing this measure (Aguilar, Arce, Hurtado, Martínez-Martín, & Thomas, 2020).

While the post-Covid period is not part of the analysis in this thesis, inflation rates increased globally after 2021. In response to rising inflation, the FED announced a tapering program, followed by a declaration that it would completely halt purchasing assets. The FED then announced that it would begin to increase interest rates to combat the rising inflation rates.

4. Literature Review

4.1. Previous Studies

This section seeks to summarize the findings of previous authors on the subject of unconventional policies, the methodologies and data they used and how the economy was affected.

Several approaches have been developed to estimate the Shadow Interest Rate in the past. One of the most well-known methods is the term structure model. This approach is widely used and has been employed in various studies, such as those conducted by Ichiue and Ueno (2006, 2007, 2013, 2015), Krippner (2014), and Wu and Xia (2016).

The term structure model involves the application of nonlinear filtering techniques to analyze shadow ratio term structure models, which were originally introduced by Black (1995). These models are designed to examine the relationships between different interest rates over time, providing valuable insights into the dynamics of interest rate movements and their implications for the economy.

Another approach that is utilized to estimate shadow interest rates is the correlation-based approach. This approach depends on the correlation between short-term interest rates and other financial and monetary variables during the period before the zero lower bound is reached. By examining these correlations, researchers aim to gain insight into the interactions and dependencies between the

financial and monetary variables within the pre-zero lower bound context. Kamada and Sugo (2006) adopt a regression-based approach to estimate Japan's Shadow Interest Rate. In their study, they regress the short-term interest rate on lending rates and a survey-based index of lending attitudes to derive the Shadow Interest Rate, which reflects the underlying economic conditions more accurately.

Another method employed by researchers utilizes a dynamic stochastic general equilibrium (DSGE) model. This model takes a new Keynesian perspective and considers the Shadow Interest Rate as the primary factor influencing the economy when the short-term interest rate reaches the zero lower bound. This approach, presented by Inchiue and Ueno (2018), offers a comprehensive understanding of the economic dynamics during periods when conventional monetary policy options are limited. By incorporating the concept of the Shadow Interest Rate, researchers gain valuable insights into the economic implications and responses under such conditions.

In his article, Krippner (2014) introduces a novel approach to modeling yield curves that accommodates the zero lower bound constraints on interest rates. Unlike other measures, this approach allows for a comparison of stimulus measures between conventional and unconventional monetary policy applications. The use of two-or three-factor models with different datasets yields estimates with lower variability.

In their article, Wu and Xia (2016) explored a non-linear term structure model to analyze an economy operating near the zero lower bound for interest rates. This approach made the model highly tractable and provided a good definition of data, especially in the context of a zero lower bound economy. The model utilized a simple factor-augmented vector autoregression (FAVAR) to calculate the shadow velocity, effectively summarizing the information from a large set of economic variables. The FAVAR model, initially proposed by Bernanke et al (2005), played a crucial role in examining the effects of monetary policy in the study. By summarizing the information from multiple economic variables using a low-dimensional factor vector, the researchers gained insights into the relationship between the policy rate and the real economy. The shadow rate term structure model allows for an analytical approach to estimate the forward rate, providing a more comprehensive understanding of the economy's dynamics in the shadow rate regime. By utilizing the shadow rate, a new monetary policy measure was constructed, which proved to be highly informative and relevant, particularly after July 2009, during the Great Recession. The continuity in the policy rate series, achieved through the use of the shadow rate term structure model, is beneficial for empirical researchers working with

vector autoregression (VAR) models to study monetary policy in macroeconomics. This continuity allows for historical analysis and updating of the policy rate data.

Lombardi and Zhu (2014) developed measures of monetary policy based on extensive datasets, particularly focusing on the shadow Federal Funds Rate. The advantage of these measurements lies in their immunity to the constraints imposed by the zero lower bound on nominal interest rates. They observed that before the 2008 Global Financial Crisis, the Shadow Interest Rates closely mirrored the effective Federal Funds Rate. During periods when the zero lower bound becomes binding, the Shadow Interest Rate has proven to be a valuable tool for gauging the stance of US monetary policy. In their study, they conducted an evaluation of monetary policy against the Taylor Rule, a guideline commonly used to assess central bank actions. The researchers employed structural vector autoregression (SVAR) models to identify monetary shocks, which provided a more accurate reflection of the FED's unconventional policy measures. The study's findings concluded that the calculated Shadow Interest Rate remained robust to different specifications and effectively captured monetary policy dynamics both pre-crisis and post the zero lower bound period. By analyzing the shadow interest rate, the researchers demonstrated that unconventional policies could effectively bridge the gap between the zero lower bound and the rates predicted by the Taylor Rule. By incorporating the Shadow Interest Rate into standard VAR models, they established that monetary policy shocks estimated in this manner offer a more realistic portrayal of US monetary policy in the post-crisis era compared to those based solely on the actual Federal Funds Rate (Lombardi & Zhu, 2014).

Leonardo et al. (2013) did a study which has an in-depth evaluation of the macroeconomic effects of unconventional monetary policies. They employed a panel vector autoregression (PVAR) model with monthly data from eight developed economies, spanning the period from the onset of the 2008 Global Financial Crisis to 2012. By utilizing data from multiple countries during the crisis period, the study aimed to strengthen the empirical analysis. The focus of the study was on examining various ways to illustrate the impact of unconventional monetary policy on macroeconomics. They specifically investigated the dynamic effects of a shock to the central bank balance sheet on production and price levels. The analysis involved studying the effects of unconventional monetary policies implemented post the 2008 Global Financial Crisis. The results indicated that an exogenous increase in central bank balance sheets at the zero lower bound led to a temporary upswing in economic activities and

inflation. However, the response to the price level was found to be weaker and less enduring compared to previous studies on the effects of interest rate shocks. Additionally, the study revealed that the effects of unconventional monetary policies were remarkably consistent across countries.

Kimura and Nakajima (2013) studied the effects of both conventional and unconventional monetary policies. Japan was an early adopter of unconventional monetary measures, initiating a quantitative easing policy in 2001, which later influenced global policy responses to the 2008 Global Financial Crisis. To analyze the impacts of these policies, the researchers employed a structural vector autoregression (VAR) model and introduced a novel framework for forecasting and identifying the effects of conventional and unconventional monetary policies using a latent threshold modeling strategy. This approach allowed for a time-varying definition of the zero lower bound of interest rates and a time-varying shrinkage of parameters, enabling the transition between conventional and unconventional policy periods. By using extensive time series data, which was available due to Japan's early implementation of unconventional monetary policies, the study examined the effectiveness of Japan's monetary policy. The findings of the study revealed that during unconventional policy periods, increasing bank reserves led to a reduction in long-term interest rates. Moreover, inflation and the output gap responded positively to changes in bank reserves. The proposed forecasting framework, combining Time-Varying Parameter-VAR and latent threshold model techniques, proved useful in detecting shocks in Japan's conventional and unconventional monetary policies. The study observed that unconventional monetary policy had a positive effect on the real economy and inflation. However, the volatility in inflation and output gap shocks increased after the 2008 Global Financial Crisis, making it more challenging to precisely measure the transmission effects on the real economy and inflation. One notable advantage of the proposed approach is its ability to analyze both conventional and unconventional monetary policy regimes without the need to divide the observation time into sub-periods. This flexibility allows for the use of the Time-Varying Parameter-VAR analysis in various economic conditions and policy scenarios. Overall, the study's innovative approach sheds light on the complex dynamics of monetary policy and provides valuable insights into the effectiveness of both conventional and unconventional measures in stimulating the economy and influencing inflation (Kimura & Nakajima, 2013).

Damjanovic and Mustang (2016) used a VAR model to investigate the impact of unconventional monetary policy in the Eurozone. The study explored the use of shadow short interest rates as an

alternative measure of policy stance when conventional linear econometric models become ineffective due to interest rates approaching the zero lower bound. The researchers applied vector autoregressive analysis to study the effects of shadow short rate monetary policy shocks for the Eurozone, Italy, and Spain, particularly during times of severe financial stress. By using Kripper's (2015) short-term Shadow Interest Rate, they examined the effects of monetary policy in the Eurozone. The empirical framework involved constructing a VAR model with a recursive ordering of variables, enabling a direct comparison with monetary policy shocks measured using conventional policy rate instruments. The findings revealed that the short Shadow Interest Rate monetary policy demonstrated dynamic effects on prices and output similar to those obtained from conventional monetary policy instruments. Moreover, it allowed for the examination of the heterogeneity between countries in the transmission of monetary policy. The study highlighted the significance of measuring monetary policy stance and analyzing its transmission in zero lower bound environments for applied macroeconomic research. Additionally, the study suggested that unconventional policies were effective in stabilizing government bond markets in 2011. However, the measures implemented by the European Central Bank (ECB) until the end of 2013 only provided limited stimulus to the real economy. Overall, the research contributed valuable insights into understanding the effects of unconventional monetary policy and the usefulness of Shadow Interest Rates as an alternative measure in analyzing the impact of monetary policy in the Eurozone (Damjanovic & Masten, 2016).

Also using a VAR model Elbourne et al. (2018) examined the impact of unconventional monetary policy on the Eurozone. The study investigated the effects of unconventional monetary policy on both the Eurozone as a whole and individual countries within it. The article utilized the Shadow Interest Rates obtained from Wu and Xia (2016). In the study, the researchers constructed an SVAR model with zero and sign constraints for identification purposes. This allowed them to estimate the effects of unconventional monetary policy shocks in the Eurozone. The identified monetary policy shocks were then used in country-level models to gain deeper insights into the effects of unconventional monetary policy. The results of the study showed weak evidence that expansionary unconventional monetary policy shocks increase output growth. However, the effects on inflation were deemed insignificant. Across the sample of countries, a range of responses was observed. These differences in output responses were largely attributed to the liquidity premium channel, confidence channel, and exchange rate channel. The study also revealed that countries with healthier banking systems and lower government debt tended to exhibit larger peak output responses to unconventional monetary

policy shocks. Nonetheless, due to the short sample period used in the study, predicting long-term effects remained challenging. Overall, the research provided valuable insights into the effects of unconventional monetary policy in the Eurozone and shed light on the varying responses of different countries to such policy measures (Elbourne, Ji, & Duijndam, 2018).

Caggiano et al. (2017) use a VAR model in the study to examine whether the real effects of uncertainty shocks are greater when the economy arrives at zero lower bound. Empirical analysis examines the real effects of uncertainty shocks and their effects in the presence of zero lower bound at normal times. The main purpose of using VAR is to investigate whether the real effects of uncertainty shocks differ when the economy is in the ZLB. The effects of uncertainty shocks and their conventional and unconventional monetary policy stances are also examined. The VAR model used in the article does not model unconventional monetary policy. Hence, the Shadow Interest Rate was founded by Wu and Xia in the article. In the article, it is determined that uncertainty shocks trigger a deeper recession in zero lower-bound periods than in unconstrained monetary policy periods. The results require studies focusing on optimal monetary policy in the presence of a Zero Lower Bound when uncertainty shocks hit an economic system (Caggiano, Castelnuovo, Giovanni, & Pellegrino, 2017).

Moder (2017) did a study examining the effect of monetary policy on the economy using the VAR model. In this study, the researcher examines the influence of the ECB monetary policy on Southeastern Europe using the Shadow Interest Rate. The research focuses on the period from 2008 to 2015, which corresponds to the implementation of unconventional monetary policy measures by the ECB. Southeastern Europe maintains significant trade connections with the Eurozone, and most investments in the region originate from the Eurozone countries. Despite the existence of different currencies in the region, all countries are directly impacted by the policies implemented by the ECB (Moder, 2017).

Using monthly data, the researchers estimated separate Bayesian Vector Autoregression (BVAR) models for each country in Southeast Europe spanning from January 2008 to December 2015. These models incorporated variables to assess the impact of European Central Bank (ECB) policy on the Eurozone, as well as specific variables for individual Southeast European countries. The study examined the effects of various macroeconomic variables, such as output and prices, and further investigated how international transmission mechanisms operated. To estimate the impact of

unconventional monetary policy shocks on each country's output, price level, and short-term interest rate, impulse response functions were utilized within a structural BVAR model. For robustness testing, the researchers employed the Shadow Interest Rate developed by Wu and Xia (2016). The identification of shocks was performed through sign and zero restrictions to generate impulse response functions. The findings of the article indicate that in the short term, output experiences a gradual increase, reaching a peak growth of 0.02% after 8 months, and then declines entirely after 21 months. Additionally, the price level exhibits a peak increase of 0.02% after 13 months. The results demonstrate that monetary expansion in the Eurozone positively influences the price level in Southeast European countries. Moreover, the output response reveals that the monetary shock has an expansionary effect. Regarding the transmission mechanism, spillovers primarily occur through the export channel. Furthermore, the study suggests that financial flows in the form of foreign direct investments or portfolio investments, not accounted for in the model, may play a significant role. Surprisingly, the exchange rate regime does not appear to affect the price level or output responses. In conclusion, this research provides valuable insights into the effects of unconventional monetary policy shocks in Southeast European countries and sheds light on the role of various transmission mechanisms and factors influencing the economic outcomes of these shocks (Moder, 2017).

Kapetanios et al. (2012) did a study analyzing the impact of monetary policy using macroeconomic data from the UK economy. Specifically, they focused on the effects of the first round of quantitative easing implemented by the Bank of England after the 2008 Global Financial Crisis. To estimate the effects of quantitative easing on output and inflation, they utilized three different models: large Bayesian VAR, change point structural VAR, and time-varying parameter VAR. The main objective of the study was to measure the broader economic effects of the central bank's asset purchases on output and inflation. Understanding the transmission mechanism of unconventional monetary policy, such as quantitative easing, was vital for assessing its effectiveness. To achieve this, the researchers adopted a counterfactual analysis, comparing the actual outcomes with what would have happened if quantitative easing had not been implemented. The datasets used for the large Bayesian VAR model included 43 variables with monthly observations from 1993 to September 2010. The structural VAR models covered a more extended period from 1963 to 2011, using both monthly and quarterly data. The variables in the model included the monthly treasury bill ratio, Ten Years Government Bond yield spreads, annualized GDP growth, CPI, and others. The analysis mainly focused on scenarios where the yield on government bonds fell by 100 basis points. The findings indicated that the decrease

in long-term government bond spreads supported GDP growth in 2009 and contributed to very low CPI inflation. The models revealed that the maximum effect on output occurred approximately 6 to 9 months after the implementation of quantitative easing, while the maximum effect on inflation emerged after 1 year. Overall, the analysis demonstrated that quantitative easing was an effective tool for stimulating the economy. However, significant uncertainties were observed in all forecasts, particularly as the forecast horizon increased. The study's results provided valuable insights into the impact and effectiveness of quantitative easing as an unconventional monetary policy tool (Kapetanios, Mumtaz, Stevens, & Theodoridis, 2012).

Miyao (2002) examined the impact of Japanese central bank policies on the economy using the VAR model. In the study, first, the working procedure of the Japanese central bank was explained. The overnight rate in the interbank money market in Japan was considered, not monetary totals. In the model, stock prices are used as a measure of asset prices in Japan. It has been argued that VAR can be a logical characterization of first differences without an error correction term. Intuitive interpretations are presented. In the VAR model used, four basic variables were selected in order to measure the effects of monetary policy in Japan; call rate (R), the monetary base (M), stock prices (Pk) industrial production (Y). Monthly observations were used for the period January 1, 1998. It was observed that monetary policy shocks have a significant and lasting effect on real output in Japan. It has been determined that the increase in money demand is due to the increase in lending to firms and households, which causes an increase in stock prices.

In Bernanke and Mihov (1995), the authors measure the impact of monetary policy on the economy by using VAR. They developed and implemented the VAR-Based model to measure the impact of the monetary policy stance on the economy. In the study, general econometric models for the monetary policy stance are discussed. Their approaches built the structural VAR model. The model they developed was the semi-structural VAR model. The model extracted information on bank reserves and Federal Funds Rate. However, it imposes simultaneous identification restrictions on many market-related variables for commercial bank reserves. By forecasting the model over different periods, they can allow for some changes in the FED's operational procedure and structural economics, while using minimal assumptions. For people who are looking for a simple indicator of policy stance, the study shows that the Federal Funds Rate was the best economic indicator before 1979. Although it lost this feature later on, it gained this feature again during the period of FED

President Greenspan. The methods using the VAR model seem to be the most ideal approach to measure the efficiency of the policy. In future studies, it has been useful to apply the methods we use in our analysis to a detailed analysis of the economy's response to policy shocks and the development of quantitative aid to federal reserve policymaking.

Modelling the economy with VAR models using shadow interest rates, Johannsen and Mertens (2018) also contribute to the literature. Specifically, in the absence of an effective lower bound, the Shadow Interest Rate is used as the nominal interest rate. Data from the US economy on interest rates, economic activity, and inflation are used to estimate the trend-cycle model. Since the predicted Shadow Interest Rates are lower than the effective lower bound, the model created predicts future short-term interest rates in the ELB, including long periods. The interest rate estimations obtained in the models were compared with the estimations of Wu and Xia (2016). By imposing short-term restrictions against Shadow Interest Rate surprises, impulse responses to monetary policy shocks are estimated. Furthermore, the stochastic volatility model produces impulse responses that change over time. The Shadow Rate model includes the inflation rate in the ELB and the three-month, two-year, five-year, and 10-year nominal interest rates. If we look at the Shadow Interest Rate approach, the dataset includes the short-term interest rate, which is the quarterly treasury rate, limited by the ELB. The nominal interest rate is assumed to be the maximum of the ELB and a Shadow Interest Rate. So that,

$$i_t = \max (s_t, ELB)$$

Although many countries around the world have negative short-term interest rates, the ELB can arise from arbitrage in bonds and cash (Johannsen & Mertens, 2018).

The study observed that monetary policy shocks identified from Shadow Interest Rate innovations had a more significant impact on yield spillovers when the ELB is in effect. This finding supports the notion that Shadow Rates capture the effects of unconventional monetary policies, as they play a crucial role in influencing the transmission of these shocks during times when conventional interest rate adjustments are limited (Johannsen & Mertens, 2018).

Lemke and Vladu (2016) did a study evaluating the impact of monetary policy on the economy in the Eurozone. In the study, Shadow Interest Rate and VAR models were used. For the Eurozone yield curve between 1999 and 2015, when bond yields turned negative, a Shadow Rate futures structure

model is proposed. In 2014, the ECB reduced the deposit rate to a negative level. Bond yields in te short and medium term also turned negative over time. The econometric model developed to calculate the yield curve is the Shadow Rate futures model without arbitrage. The model provides a time-varying and negatively effective lower bound (Vladu & Lemke, 2017).

The model estimates describe a significant change in the market's perception of the effective lower bound from 1 basis point to minus 11 basis points. It was found that an announcement of a decrease in the lower bound can reduce the yield curve even if the lower limit is not yet evident (Vladu & Lemke, 2017).

The studies analyzed in this section show that shadow interest rates and unconventional policies have been of interest to researchers in the monetary policy debate preceding and following the 2008 Global Financial Crisis. The summary highlights that the research question of this thesis, i.e., to what extent the use of shadow interest rates yields differences in the response of the economy, is worth pursuing further.

5. Model

5.1. Origins of the Model

Vector Autoregression (VAR) models were introduced by Sims (1980). Sims suggested the use of the VAR model in several articles, with “Macroeconomics and Reality” being one of the most significant. In this article, Sims developed the VAR model to model the co-dynamics and causality between a set of macroeconomic variables. The VAR model is a statistical tool that shows the behavior of multiple economic variables over time. He assumes that each variable in the system is affected by the past values of all the variables in the system, with each variable potentially impacting the others simultaneously. This approach allows for the modeling of complex interactions between multiple economic variables, providing valuable insights into the dynamics of the economy. Sims’s work on the VAR model has had a significant impact on macroeconomic research and has led to numerous applications in various fields, including finance, business, and economics.

In this article, Sims (1980) stated that VAR models can be used for three purposes: (1) predicting economic time series, (2) designing and evaluating economic models, and (3) evaluating the consequences of alternative policy actions. He also noted that the assumptions made before

introducing his VAR model were insufficient for estimating these targets. Econometric models, before Sims introduced the VAR model, were variable shifts in either the supply curve or the demand curve. Sims developed the VAR model as an alternative model to the standard econometric models with doubtful exclusion restrictions. Alternatives generally treat all variables endogenously and allow for rich dynamics (Lawrence, 2012). Restrictions are usually enforced by statistical tools. VAR has been recognized by Sims as an n-variable linear model with an n-equation, in which each variable can be explained in turn by its lagging value plus the current and past value of the remaining n-1 variable. Sims (1980) suggested that VAR models are an efficient way to organize data (Lawrence, 2012).

Definition of a VAR set as an example. The N x 1 vector Y_t represents the set of variables of interest in its analysis. The assumption that Y_t follows a pth-order VAR can be expressed as:

$$Y_t = B_0 + B_1 Y_{t-1} + \cdots + B_p Y_{t-p} + u_t, \qquad Eu_t u_t = \mathrm{V}$$

where u_t is not associated with Y_{t-1}... Y_{t-p}. Since it is assumed that a large enough value is assigned to p, u_t does not autocorrelate over time (Lawrence, 2012).

5.2. How to Calculate Shadow Interest Rate

Differing from the observed short-term interest rate, the Shadow Rate, originally introduced by Fischer Black in 1995, doesn't have a lower bound constraint of 0%. Whenever the Wu-Xia Shadow Rate exceeds 1/4%, it is precisely equivalent to the model-predicted one-month interest rate as a result of its construction.

The input data utilized in the Wu and Xia (2016) model comprises one-month forward rates starting n years in the future. Wu and Xia (2016) consider forward rates corresponding to time frames of n = 1/4, 1/2, 1, 2, 5, 7, and 10 years. These forward rates are derived from end-of-month Nelson-Siegel-Svensson yield curve parameters extracted from the Gurkaynak, Sack, and Wright (2006) dataset.

Wu and Xia (2016) assume that the short-term interest rate is the maximum of the Shadow Rate S_t and a lower bound r:

$$r_t = \max(r, S_t).$$

If the Shadow Interest Rate (S_t) exceeds the lower bound, it becomes the short rate. When the lower bound is in effect, the Shadow Rate conveys more economic information than the short rate. Since late 2008, the FED has set the annual interest rate on reserves at 0.25%, suggesting r=0.25%.

In the following the outlines of the model of Wu and Xia (2016) are explained. Since their metric is used in this thesis, the discussion and notation closely follow their exposition. They assume that the Shadow Interest Rate S_t is an affine function of some state variables X_t

$$S_t = \delta_0 + \delta_1 X_t$$

The state variables evolve according to a first-order vector autoregressive process (VAR (1)) under the physical measure (P).

$$X_{t+1} = \mu + \rho X_t + \sum \varepsilon_{t+1}\,,\ \varepsilon_{t+1} \sim N(0, I).$$

The logarithm of the stochastic discount factor exhibits an essentially affine behavior, akin to Duffee's findings.

$$logM_{t+1} = -r_t - \frac{1}{2}\lambda_t{}'\lambda_t - \lambda_t{}'\varepsilon_{t+1}$$

The price of risk (λ_t) exhibits a linear dependence on the factors.

$$\lambda_t = \lambda_0 + \lambda_1 X_t$$

This suggests that the dynamics of the factors under the risk-neutral measure (Q) also follow a VAR (1) process.

$$X_{t+1} = \mu^Q + \rho^Q X_t + \sum \varepsilon_{t+1}^Q,\ \varepsilon_{t+1}^Q \sim N(0, I).$$

The parameters under the P and Q measures are connected in the following manner:

$$\mu - \mu^{Q} = \sum\lambda_0,$$
$$\rho - \rho^{Q} = \sum\lambda_1$$

5.3. Method Used in the Thesis

The method used in the thesis is the Vector Autoregression (VAR) model, which is a commonly used technique in time series research. The VAR model allows for the examination of dynamic relationships between variables that interact with each other over time. By using the VAR model, researchers can analyze how changes in one variable impact the other variables in the system and observe the patterns and responses over multiple time periods. This makes it a valuable tool for understanding the interdependencies and interactions among various variables in a time series dataset. Econometric analyses utilize a reduced VAR model. The structural VAR model is a variation of the unrestricted VAR model, which is used to predict multiple variables in an analysis (Hamilton, 2020).

The VAR model represents every variable as a vector. For example, suppose we have a vector of time series data Y_t. Mathematically, a VAR model with K variables and lags can be expressed as follows:

$$Y_t = B_1 Y_{t-1} + \ldots + B_p Y_{t-1} + u_t$$

Y_t is B_0 and k × 1 column vectors and B_0, B_1, B_2, …, Bp is k × k coefficient matrices. The simplest VAR model for three variables is lagged and can be expressed as follows.

$$\begin{bmatrix} Y_1(t) \\ Y_2(t) \\ Y_3(t) \end{bmatrix} = \begin{bmatrix} B11 & B12 & A13 \\ B21 & B22 & A23 \\ B31 & B32 & A33 \end{bmatrix} \text{ x } \begin{bmatrix} Y1(t-1) \\ Y2(t-1) \\ Y3(t-1) \end{bmatrix} + \begin{bmatrix} U_1(t) \\ U_2(t) \\ U_3(t) \end{bmatrix}$$

Testing for stationarity is crucial in time series analysis, including in VAR models. The Augmented Dickey-Fuller (ADF) test is one of the most commonly used methods to test for stationarity in a time series. In the Augmented Dickey-Fuller (ADF) test, the null hypothesis assumes the presence of a unit root, which indicates that the time series under consideration is non-stationary. Non-stationary time series exhibit trends, random walks, or cyclical pattern, making them unsuitable for certain statistical analyses and modelling techniques.

However, if the test statistic derived from the ADF test is smaller than the critical value, it provides evidence to reject the null hypothesis. In this case, we conclude that the time series is stationary, meaning that it lacks significant trends or systematic patterns over time. Stationary time series possess

constant mean, variance, and covariance characteristics, making them more amenable to various statistical analyses, forecasting, and modeling approaches.

By identifying stationary time series through the ADF test, researchers can confidently utilize these data in applications such as econometric modeling, time series forecasting, and other statistical investigations that rely on the assumptions of stationarity for meaningful results.

If the time series is found to be non-stationary, differencing can be applied to make it stationary. This involves taking the difference between each observation and its lagged value. By making the time series stationary, we can ensure that the VAR model will produce reliable results. Impulse response functions are important to understand how a shock to one variable affects the other variables in the system over time.

The impulse response function is typically displayed graphically, showing the changes in each variable's value over time following the shock. The lines on the graph represent the response of each variable, while the shaded areas around the lines represent the 90% confidence interval. This interval provides a range within which we can be 90% confident that the true response lies.

By analyzing the impulse response functions, we can gain insight into the transmission and dynamics of the shock across the variables in the VAR model. This information is useful for understanding the interdependencies and spillover effects within the system, as well as for policy analysis and forecasting.

5.4. The Model Used in the Thesis

The vector autoregression (VAR) model stands as one of the most successful approaches in the analysis of multivariate time series data. As an extension of univariate autoregressive models to multiple variables, the VAR model proves to be highly valuable in understanding the dynamic behavior of economic and financial time series. Its flexibility makes it particularly useful for forecasting, allowing for versatile and adaptable predictions in a wide range of scenarios (Hamilton, 2020).

VAR(p) model of order p can be represented as follows.

$$Y_t = \mathrm{B}_1\mathrm{Y}_t + \mathrm{B}_2\mathrm{Y}_{t-2} + \ldots + \mathrm{B}_p\mathrm{Y}_{t-p} + \varepsilon_t$$

Y_t=(Y_{1t} ...Y_{kt}) represents each (kx1) vector of time series variables. B_i = (i = 1,2...p) represents a (k x k) parameter matrix and ε_t a (kx1) random error vector.

A bivariate VAR model with time t on another variable at time t-1 is represented as follows.

$$Y_t = c + B(L)Y_{t-1} + u_t$$

$Y_t = (y_{1t}y_{2t})$) , B_t = $[(\beta 11 \& \beta 12 \& \beta 21 \& \beta 22)]$ and $U_t = (u_{1t}u_{2t})$, C = (c_1c_2)

$$(y_{1t}y_{2t}) = (c_1c_2) + [(\beta 11 \& \beta 12 \& \beta 21 \& \beta 22)] + ((Y_{1t-1})(Y_{2t-2})) + (u_{1t}u_{2t})$$

Each equation can be written separately as follows:

$Y_{1t} = c_1 + \beta_{11}Y_{1t-1} + \beta_{12}Y_{2t-1} + u_{1t}$

$Y_{2t} = c_2 + \beta_{21}Y_{1t-1} + \beta_{22}Y_{2t-1} + u_{2t}$

The VAR model used in this study follows the setup in Schenkelberg & Watzka (2013), who model unconventional monetary policy in Japan. Overall, four models are used, with each model including the following variables: CPI_t represents Consumer Price Index, GDP_t represents Gross Domestic Product, GBY^{US} and GBY^{Euro} represent 10 years Government Bond Yields of the respective countries that are analyzed, EUR_t represents Euribor, FFR_t represents Federal Funds Rate, SIR^{US}_t and SIR^{Euro}_t represent Shadow Interest Rate for the US and the Eurozone, respectively and RER_t represents Real Exchange Rate.

The models are as follows:

1) $Y_t^{US1} = (CPI_t, GDP_t, FFR_t, GBY^{US}_t, RER_t)$

2) $Y_t^{US2} = (CPI_t, GDP_t, SIR^{US}_t, GBY^{US}_t, RER_t)$

3) $Y_t^{EU1} = (CPI_t, GDP_t, EUR_t, GBY^{Euro}_t, RER_t)$

4) $Y_t^{EU2} = (CPI_t, GDP_t, SIR^{Euro}_t, GBY^{Euro}_t, RER_t)$

Models 1 and 2 model the US economy use the same variables, but whereas model 1 includes the short term policy rate in the US, the Federal Funds Rate, the second model includes the Shadow Interest Rate measure of Wu and Xia (2016) for the US. Similarly, models 3 and 4 model the economy of the Eurozone with the short term policy rate Euribor, and the Shadow Interest Rate measure of Wu and Xia (2016) for the Eurozone, respectively.

The Bayesian Information Criterion (BIC) was used to determine the appropriate number of lags to add to the estimation equation. For all four models the BIC indicates that two lags are appropriate for estimation.

5.5. Data Used in the Thesis

All the data used in the thesis are collected quarterly. The time frame of the analysis spans from 2004Q4 to 2022Q2. The choice of this time period is related to the fact that the use of unconventional policies is relevant for the period after 2008 and prior to 2023. However, an analysis for selected variables is presented in subsection 6.4. in order to compare the difference in impulse responses when the Covid period is excluded. In addition to interest rates, other relevant variables are considered, such as the Real Exchange Rate, Consumer Price Index (CPI), Ten Years Government Bond yield, and the GDP. All data series are seasonally adjusted.

To ensure the stationarity of the data, logarithms are applied to variables other than interest rates and bonds, and detrended prior to estimation.

In the following, impulse responses are presented and discussed for the four models that were outlined above. Specifically, of interest is the comparison in the responses of various variables, when short term policy rates are used and when shadow interest rates are used.

6. Impulse Response Functions

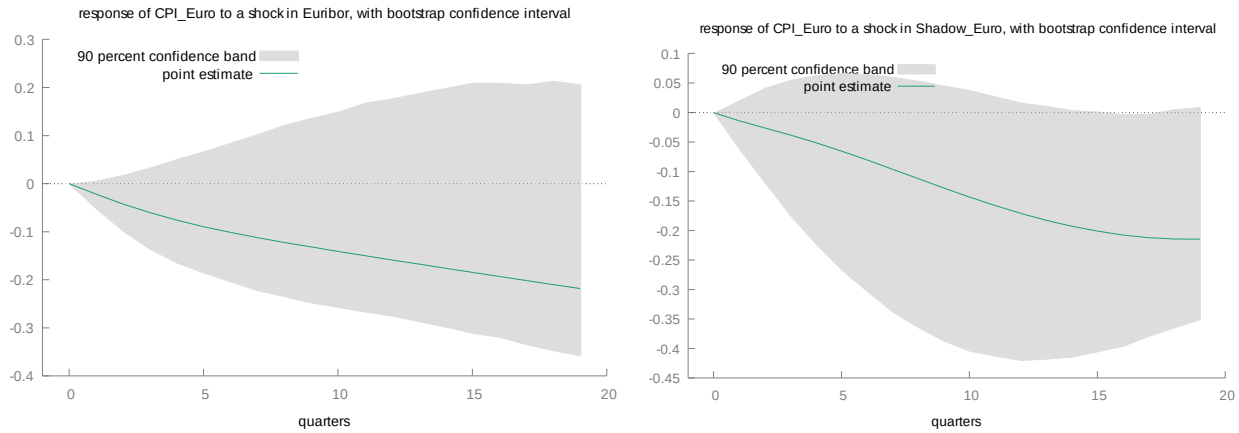
Impulse response functions (IRFs) are a crucial component of VAR analysis. They provide insight into the dynamic interactions and response patterns between variables in a VAR model when subject to shocks. By examining IRFs, researchers can assess the magnitude, direction, and duration of the effects resulting from particular shocks.

By analyzing IRFs, researchers can examine the transmission mechanisms of shocks, assess the persistence of effects, and evaluate the relative importance of different variables in the system. IRFs can help quantify the magnitude of the responses and identify any significant and lasting effects.

In the following IRFs, only one data was shocked and how another variable reacted to the shocked data was analyzed.

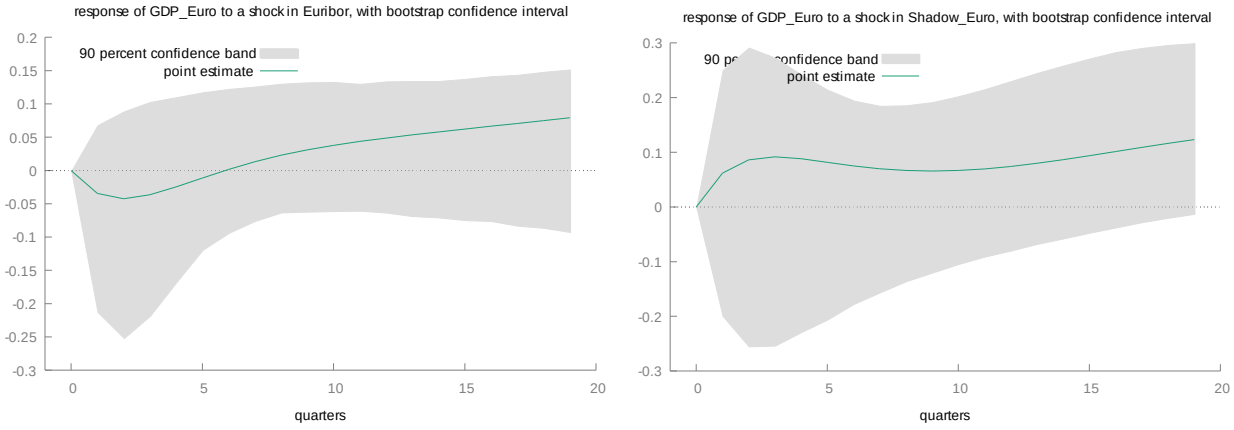
6.1 Impulse Response Functions of variables When Euribor and Shadow Interest Rate in the Eurozone are Shocked

Graph 9. Response of CPI to a shock in Euribor and Eurozone Shadow Interest Rate



The response of CPI to both interest rate forms is in accordance with economic theory, as there is a decrease in prices when there the ECB tightens monetary policy. However, the response of CPI when the shadow interest rate is used is qualitatively and quantitatively more in accordance with economic theory when the confidence bands are taken into account: prices move more into the negative territory in comparison to the response of CPI when the short term policy rate of the ECB is used.

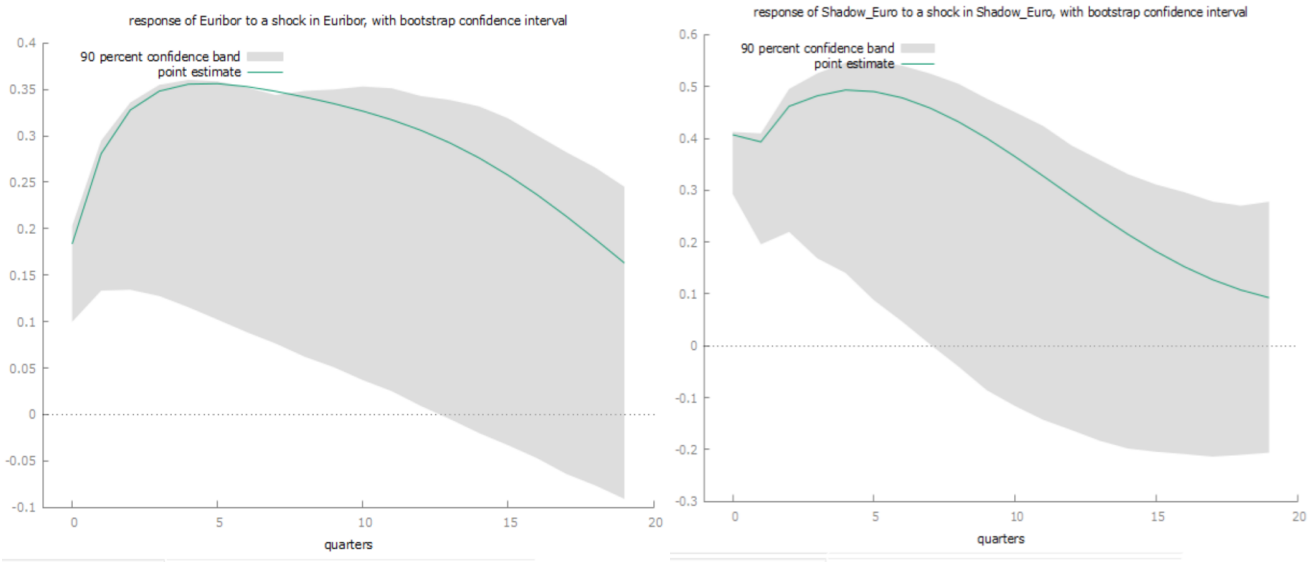
Graph 10. Response of GDP to a shock in Euribor and Eurozone Shadow Interest Rate



The response of output to monetary tightening is similar for both measures as there is an overall increase. However, there is an initial decrease in output when the short term policy rate is used, while there is an initial increase in output when the shadow interest rate is used. The overall increase is an

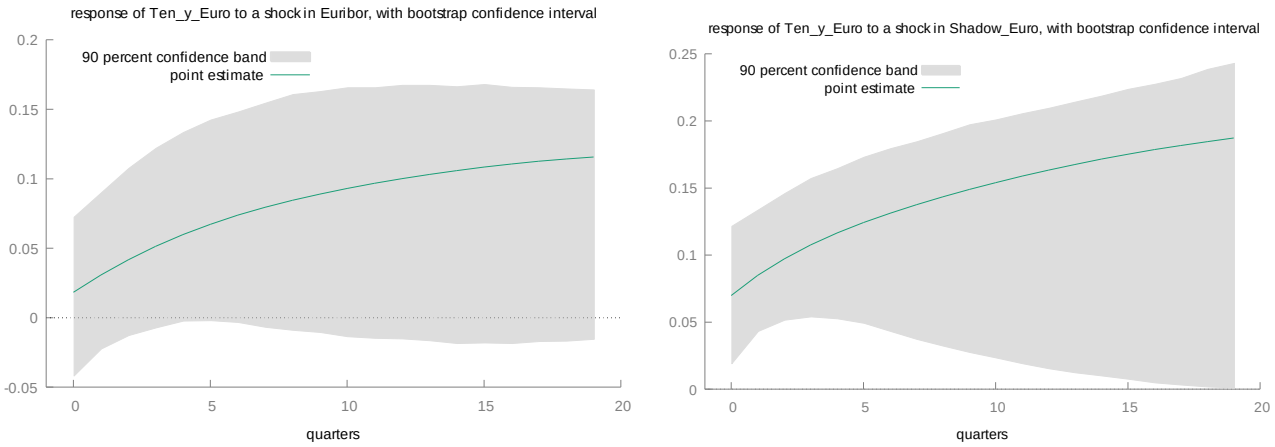
interesting result as monetary tightening is usually associated with decreases in output. But the period that is analyzed in this thesis has several interesting features, such as multiple severe crises of various duration (2008 financial crisis as well as the Covid period) such that unconventional results might be a reflection of that. As an interesting feature, results become more "conventional" when the Covid period is excluded and is mostly negative for both measures of the interest rate.

Graph 11. Response of Euribor and Eurozone Shadow Interest Rate when shock in Euribor and Eurozone Shadow Interest Rate



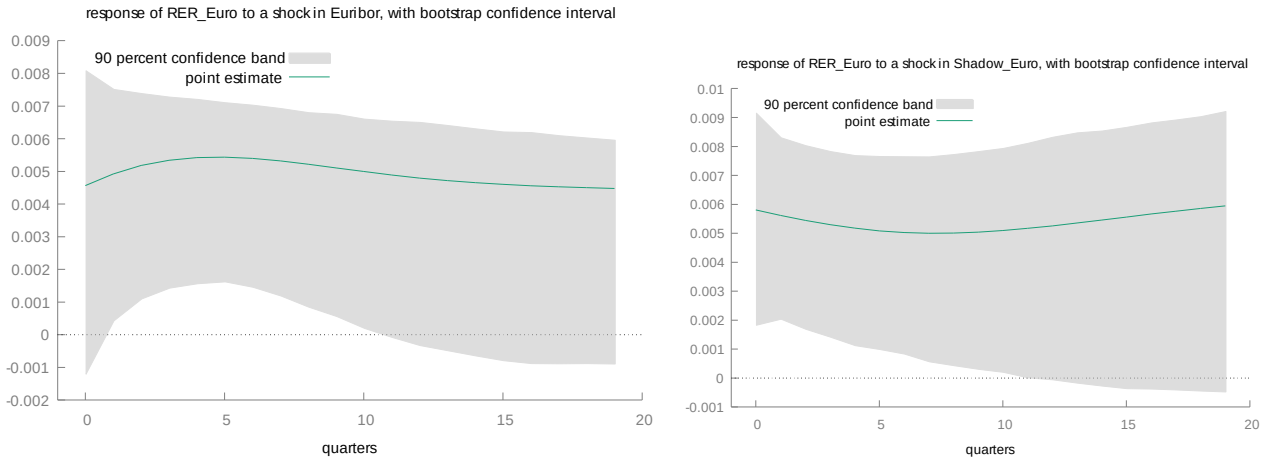
The response of Euribor to a shock in Euribor and the Shadow Interest Rate to a shock in the Shadow Interest Rate are positive as expected with a significant initial increase and a gradual decrease.

Graph 12. Response of Ten Years Government Bond Yields to a Shock in Euribor and Eurozone Shadow Interest Rate



The response of Ten Years Government Bond yields to a shock in both the Euribor and the Shadow Interest Rate is that of a steady increase. The effect of tightening measures on long-term yields is a topic that has been discussed in the literature and there is no consensus on what the response should look like (see discussion in e.g. Schenkelberg and Watzka, 2013 for a discussion of this issue). While theory could suggest that there will be a decrease in long-term yields due to falling inflation expectations, the results of the analysis presented in this thesis suggest that both measures of the interest rate yield in increasing long-term yields as in Schenkelberg and Watzka (2013) with a stronger reaction in the model with the Shadow Interest Rate.

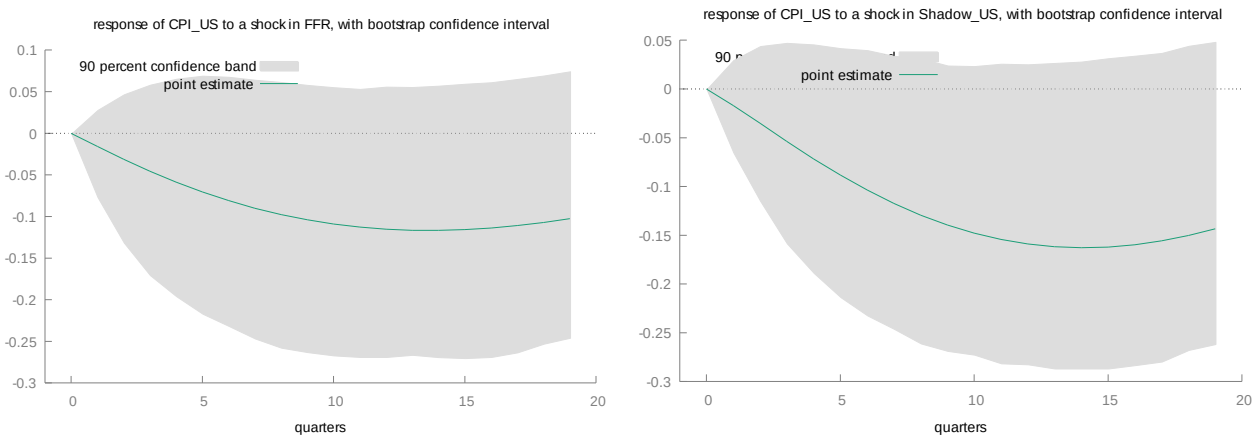
Graph 13. Response of Real Exchange Rate to a Shock in Euribor and Eurozone Shadow Interest Rate



The response of the real exchange rate in response to an increase in the short term policy rate and the shadow interest rate is positive, consistent with expected economic theory. However, the response to an increase in Shadow Interest Rate is stronger, implying again that although the results are similar qualitatively, it is important to use the proper measure to understand the reactions quantitatively.

6.2 Impulse Response Function When Shock in Federal Fund Rate and Shadow Interest Rate in USA

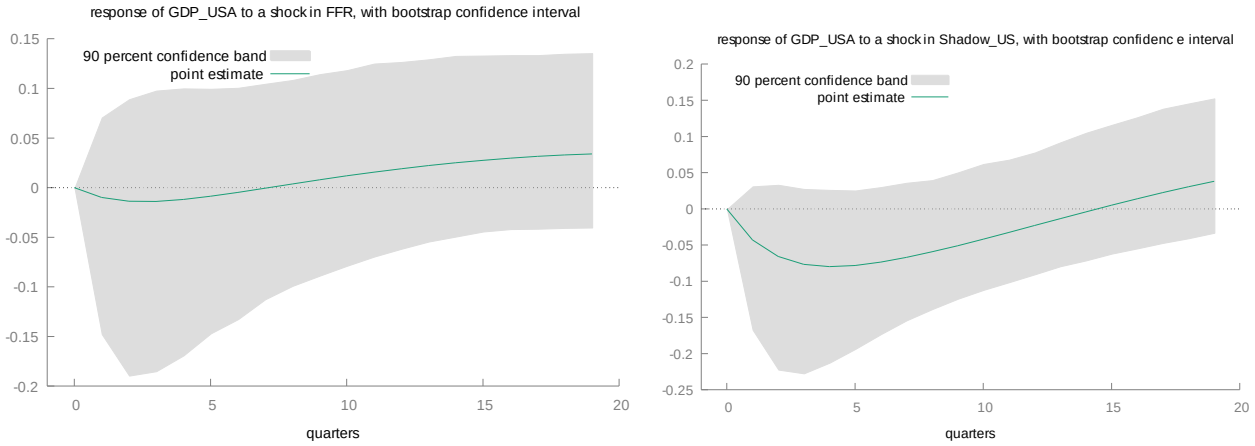
Graph 14. Response of CPI to a Shock in Federal Funds Rate and USA Shadow Interest Rate



For the US, the response of CPI to a shock in both the Federal Funds Rate and the Shadow Interest Rate is negative.

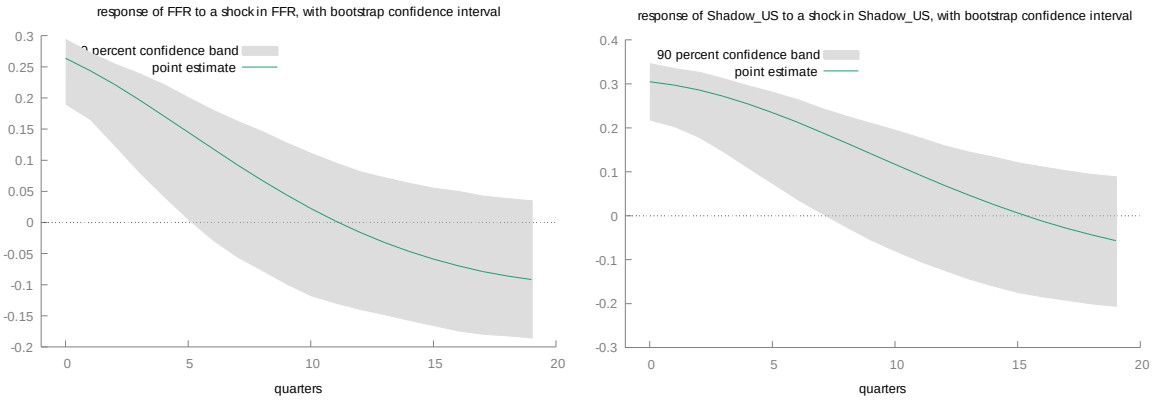
Also for the US, the response of prices to both interest rate forms is in accordance with economic theory, with a decrease in prices when there the FED tightens monetary policy. An interesting note on the response of prices in all four models is that there doesn't seem to be a price puzzle (see e.g. Hanson, 2004), i.e. an increase in prices to monetary tightening. The response of CPI is qualitatively similar for both measures, with the difference that the price decrease is stronger and dissipates more gradually when the Shadow Interest Rate is used.

Graph 15. Response of GDP to a Shock in Federal Funds Rate and USA Shadow Interest Rate



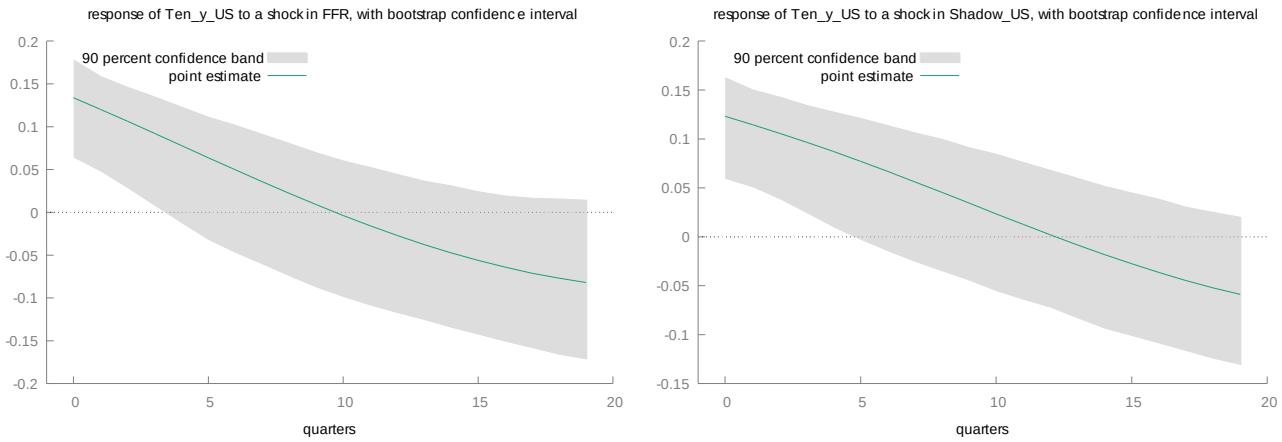
Impulse responses of GDP to monetary tightening imply an initial negative response for both measures that are utilized and an eventual positive response. Similar to previous results though, the response of output to increases in the Shadow Interest Rate are more strong and more gradual in comparison to the model that utilizes the Federal Funds Rate: output increases again after five quarters in the first model while there is an increase after 15 quarters in the second model.

Graph 16. Response of Shock in Federal Funds Rate and USA Shadow Interest Rate to a Shock in Federal Funds Rate and USA Shadow Interest Rate



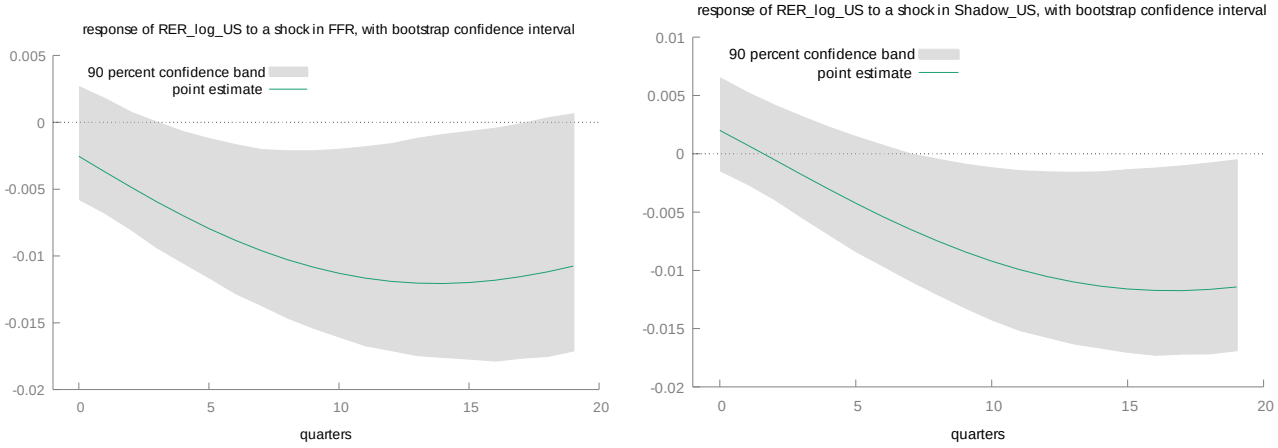
The response of Federal Funds Rate to a shock to itself and the Shadow Interest Rate to a shock to itself are positive as expected with a significant initial increase and a gradual decrease. However, the rates turn negative after 10 quarters for both measures of the interest rate.

Graph 17 Response of Ten Years Government Bond Yields to a Shock in Federal Funds Rate and USA Shadow Interest Rate



When we examine the responses of Ten Year Government Bond yields to shocks in the Federal Funds Rate and the Shadow Interest Rate, it becomes evident that the responses are qualitatively and quantitatively very similar for both interest rate measures, with an initial increase in the long-term yield and an eventual decrease after around 10 quarters. In contrast to the response of long-term yields for the Eurozone, the response for the US turns negative eventually, highlighting that the response is more complicated than a binary response. This may also be related to the size of bond markets in the US as compared to the Eurozone.

Graph 18. Response of Real Exchange Rate to a Shock in Federal Funds Rate and USA Shadow Interest Rate



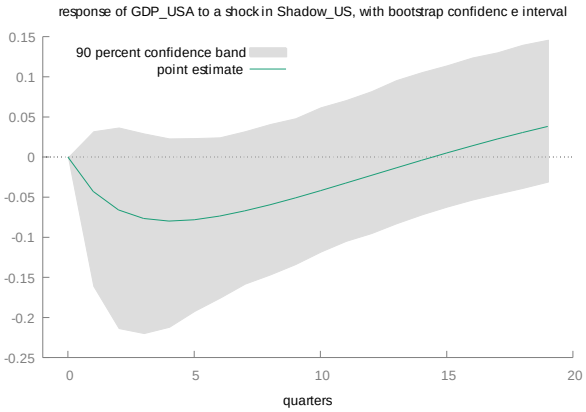
The response of the real exchange rate when the short term policy rate is used is negative. In contrast to this, the response when the Shadow Interest Rate is used, the response is positive at first and eventually turns negative. The response to the second measure corresponds more to economic theory as the real exchange rate is expected to increase in response to monetary tightening but implying that the overall response is negative.

6.3 Impulse Response Comparison When the Covid-19 Period is Excluded in the US

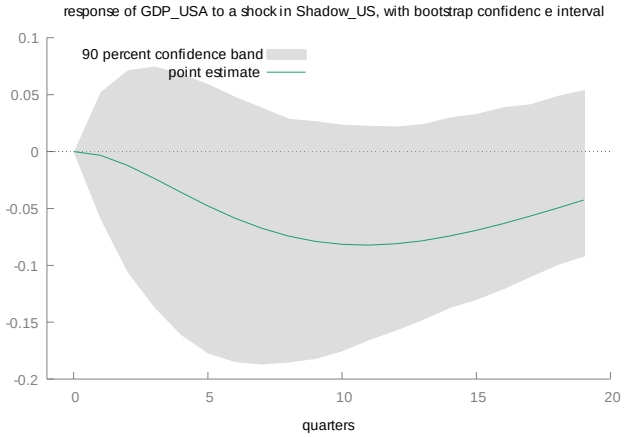
Graph 19. Response of GDP to a Shock in USA Shadow Interest Rate Including and Excluding Covid-19 Period

As an additional analysis, the response of GDP to increases in the Shadow Interest Rate is analyzed when the Covid period is excluded (i.e. the sample spans 2004-2019) and when it is included (i.e. 2004-2022). This is because the Covid period resulted in short-lived but very steep increases and decreases in output for both the US and the Eurozone, and it may be potentially of interest to produce the impulse response functions without the Covid period.

IRF including the Covid-19 period



IRF Excluding the Covid-19 period

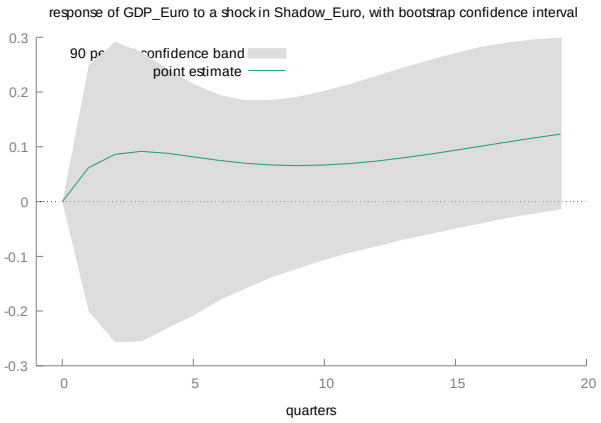


The response of output to increases in the Shadow Interest Rate when the Covid period is included (Graph 15) exhibits an initial decrease and an eventual increase. In contrast, the response when the Covid period is excluded is qualitatively and quantitatively more negative and stronger.

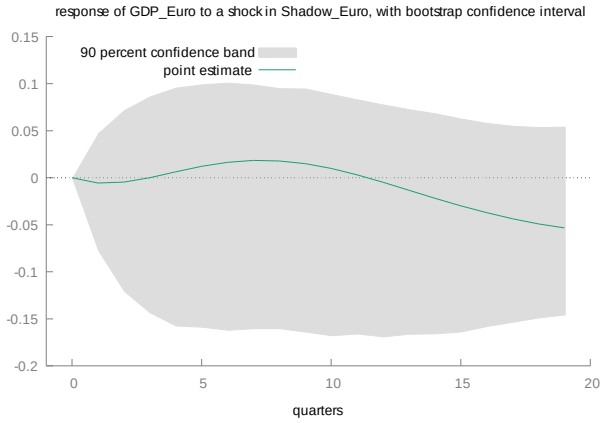
6.4 Impulse Response Comparison When the Covid-19 Period is Excluded in the Eurozone

Graph 20. Response of GDP to a Shock in Eurozone Shadow Interest Rate Including and Excluding Covid-19 Period

IRF including the Covid-19 period



IRF excluding the Covid-19 period



For the Eurozone, there are significant differences in the response of output to increases in the Shadow Interest Rate: the full sample, including the Covid-19 period exhibits an initial increase and an eventual increase in output, while the restricted sample excluding the Covid-19 period exhibits an initial, subsequent decrease and an eventual decrease in output. The qualitative difference in the

responses implies that the Covid-19 period is associated with short-lived but very significant movements in output, implying that the time period is an important factor in understanding the results.

7. Discussion and Conclusion

The 2008 financial crisis necessitated many central banks around the globe to implement policies that are considered unconventional. Having reached the zero lower bound within a relatively short period of time these central banks used policies, elements of which were implemented previously by the Bank of Japan as a response to the so-called lost decade.

Setups such as the VAR model use time series to explain the dynamic relationship between different variables. For monetary policy analysis, one of the key variables is the short term policy rate of the central bank. In the post-2008 period the policy rate reached the zero lower bound in countries such as the US and in the Eurozone and hence may result in potentially wrong interpretations. Considering this point, the analysis in this thesis compares the responses of several variables within a VAR setup when the interest rate is used that is bounded by the zero lower bound and the shadow interest rate, which is not bounded and can be negative.

The results indeed show that it is imperative to take this background into account since there are qualitative and quantitative differences in the responses of economic variables for the different interest rates that were used. The estimation period includes the Covid-19 pandemic as well, a period with a significant decrease and subsequent increase in output and unconventional policies that accompanied these movements. To analyze this period, an additional analysis was performed that excluded the Covid-19 period. The results indicate qualitative and quantitative differences: the period that excludes the Covid-19 period results in more “conventional” responses.

The present study focused on the implications on monetary policy, but future research could analyze the interaction between other variables and potential dynamic responses that could be of interest for other areas.

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