U.PORTO

FEP FACULDADE DE ECONOMIA UNIVERSIDADE DO PORTO

THE PERMANENCE OF THE ZERO LOWER BOUND IN THE EURO AREA: A MATTER OF MONETARY POLICY FRAMEWORK?

Daniel Monteiro Marques

Dissertation

Master in Economics

Supervised by

Manuel António da Mota Freitas Martins

2020

Acknowledgements

My first words of gratitude must go to my supervisor, Professor Manuel António da Mota Freitas Martins, for his guidance throughout this challenging journey of writing a dissertation. It was a tough work. Yet, with his help, it was not as tough. His availability to discuss, question, and encourage my work was of the utmost importance for this final result.

I would also like to thank my mother, Helena, for being always there for everything I need.

To my father, Joaquim, I would like to thank as well.

Abstract

The Zero Lower Bound (ZLB) has become a serious constraint for the conventional conduct of monetary policy, especially since the outbreak of the Global Financial Crisis (GFC). Even more prominent has been its permanence over time.

It is then of the utmost importance to understand the origins of this phenomenon. In this context, it will be assessed whether inflation targeting – which managed to reduce high and volatile inflation rates of the past – may have become a victim of its own success. In fact, by promoting a low inflation rate environment, it naturally reduced the cushion of central banks to cut official interest rates in the face of negative shocks, so that real interest rates are lowered as well. Against this backdrop, the severity of the GFC may have exposed that the margin that monetary policymakers had to reduce nominal interest rates may have not proved enough, particularly when the economy is hit by deep recessions.

Although the current weakness of inflation targeting may have played its role, an important conclusion of this dissertation is that the secular decline observed in natural real interest rates may have been the main responsible for the permanence of the ZLB in the developed world.

In order to address this challenge, a broad range of economists and policymakers have come up with alternative proposals to inflation targeting. Among them, this dissertation gives particular attention to price-level targeting, and after comparing the simulated values to the observed ones for the euro area since 2009Q3 until 2019Q4, it concludes that a timely adoption of price-level targeting in the euro area could have prevented the euro area from bearing the costs of the ZLB. However, this result should be understood carefully because a decline in natural real interest rates may constrain policy regardless of the regime.

JEL codes: E31; E52; E58

Keywords: Zero Lower Bound; Global Financial Crisis; Monetary Policy Framework; Inflation Targeting; Price-Level Targeting

Resumo

O *Zero Lower Bound (ZLB)* tornou-se numa restrição importante à condução tradicional da política monetária, em especial depois do surgimento da Grande Recessão (GR). Particularmente relevante foi a sua permanência ao longo do tempo.

É, assim, imperativo perceber as origens que estão na base deste fenómeno. Neste sentido, será avaliado se o *inflation targeting* – o qual contribuiu para a redução das elevadas e voláteis taxas de inflação do passado – se poderá ter tornado numa vítima do seu próprio sucesso. Através da promoção de um ambiente de baixa inflação, o *inflation targeting* reduziu inevitavelmente a margem que os bancos centrais tinham para cortar as taxas de juro diretoras na presença de choques negativos, por forma a que as taxas de juro reais também diminuam. Assim, a GR pode ter exposto que a margem que os decisores de política monetária têm para baixar as taxas de juro nominais poderá não ser suficiente, particularmente quando a economia é atingida por recessões económicas profundas.

Embora o *inflation targeting* possa ter tido o seu devido papel, esta dissertação permite concluir que a diminuição tendencial observada nas taxas de juro reais naturais poderá ter sido a principal responsável para a permanência do *ZLB* no grupo dos países mais desenvolvidos.

Um grande número de economistas sugeriu, assim, alterações ao regime atual de *inflation targeting*. Esta dissertação, por sua vez, deu particular atenção ao *price-level targeting*, e após comparar os valores simulados com os valores observados para a área do euro entre 2009T3 e 2019T4, foi possível concluir que uma atempada adoção do *price-level targeting* na área do euro poderia ter evitado a ocorrência do *ZLB*. No entanto, este resultado deverá ser analisado com cuidado, uma vez que a tendência decrescente nas taxas de juro reais naturais pode continuar a condicionar a política, independentemente do regime utilizado.

Códigos JEL: E31; E52; E58

Palavras-chave: *Zero Lower Bound*; Grande Recessão; Enquadramento de Política Monetária; *Inflation Targeting*; *Price-Level Targeting*

Table of Contents

List of Figures

List of Tables

1 Introduction

The Zero Lower Bound (ZLB) has become a serious constraint for the conduct of monetary policy, especially since the outbreak of the Global Financial Crisis (GFC). Even more prominent has been its permanence over time (Bernanke, 2019; Bernanke, Kiley, & Roberts, 2019; Brainard, 2019; Mertens & Williams, 2019).

In this context, given the need to stimulate the aggregate demand, accommodative monetary policy was required in most of the advanced economies and the euro area was no exception. Central banks had to ensure a decrease in real interest rates so that the levels of output and inflation recovered towards the levels before the 2007-2009 financial crisis.

However, the low inflation environment – which was noticeably achieved by the implementation of inflation targeting in the 1990s – was exacerbated at least temporarily by the severity that characterised the GFC. Indeed, although economic agents in the euro area continue to believe in the credibility of inflation targeting, as long as the long-term inflation expectations remain well-anchored around 2 percent, the constant undershooting of the inflation target may have decisively contributed to the observed decrease in one-year-ahead inflation expectations.

Having this in mind, an even further decrease of nominal interest rates is required to reduce real interest rates and thus stimulate both output and inflation. Nevertheless, given the possibility of holding cash with a zero nominal return, nominal interest rates have a lower bound that restrains how further they can be reduced (Beyer & Wieland, 2019). It is typically assumed to be equal to zero, but it may even be lower because the storage and insurance costs may be meaningful. Therefore, despite the valuable performance of inflation targeting during the Great Moderation (GM) in reducing low and volatile inflation rates, the emergence of the GFC and the resulting ZLB may have raised the question of whether inflation targeting may have become a victim of its own success (Gillitzer & Simon, 2015).

In other words, the permanence of the ZLB may have called into question the weakness of inflation targeting in addressing severe economic slowdowns of the same magnitude of the GFC. If this proves to be true, it would be possible to conclude that the permanence of the ZLB in the developed world, especially in the euro area, could have been a matter of monetary policy framework. If not, then it would be also of the utmost importance to understand the reasons behind that recent tendency.

Against this backdrop, this dissertation aims not only at figuring out the reasons that may have contributed to the permanence of the ZLB, but also proposing alternatives that may prove more suitable to address it. In a nutshell, the goal of this dissertation is to investigate whether inflation targeting, as it has been designed and put into practice, may have proved ineffective in facing severe shocks, or whether some structural changes may have occurred, hence exempting at least the direct responsibility of inflation targeting for the tough and protracted recovery in the aftermath of the GFC.

To do so, this dissertation will describe the well-known financial crisis in order to highlight the particular severity that it has imposed in the most advanced economies, particularly in the euro area alongside with a sovereign debt crisis. Some literature on the ZLB will also be provided so as to better understand its implications for the standard conduct of monetary policy. Indeed, the ZLB has resulted in the employment of unconventional monetary policy tools across the developed world, namely quantitative easing, forward guidance, negative interest rates, and yield curve control, whose adoption will be described as well. Notwithstanding this unusual monetary easing, the trajectory of real Gross Domestic Product (GDP) in the most advanced economies is still below its pre-crisis trajectory, as well as inflation rates have not consistently bounced back towards the announced inflation target. This has paved the way to begin thinking that some structural changes may have occurred under the developed world.

And even if inflation targeting may have had only a small responsibility for the occurrence of a binding ZLB in the euro area, the analysis of alternative proposals to inflation targeting will also be of the utmost importance so as to discuss which properties a monetary policy framework should have in order to be more suitable than inflation targeting to cope with the ZLB. In this regard, this dissertation will address the following four alternatives: raising the inflation target, price-level targeting, temporary price-level targeting, and nominal GDP targeting.

In particular, price-level targeting will receive more attention throughout this dissertation since its expected impact on inflation expectations, inflation rates, output gap, and short-term nominal interest rates will be simulated for the euro area between 2009Q3 and 2019Q4, and then compared to the observed values for those variables.

An important conclusion from this simulation exercise is that the timely adoption of price-level targeting could have precluded the euro area from being hit by the ZLB. This result

then gives power to the thesis that inflation targeting may have become a victim of its own success and thus should be replaced by a policy regime that proves better suited to address severe economic recessions – as price-level targeting proves throughout the simulation held.

However, these simulation results should be read carefully because the simulation methodology is not without its drawbacks, and Holston, Laubach, and Williams (2017), and Beyer and Wieland (2019) have estimated a secular decline in natural real interest rates. As it is easily understood, a downward trend in natural real interest rates means that an even lower real interest rate is required so that monetary policy is expansionary. And given that nominal interest rates are not able to be reduced further below zero or a small negative value, the ZLB is likely to become a more frequent binding constraint henceforth.

To sum up, despite the simulation employed shows the contrary, that is, the adoption of price-level targeting would have prevented the euro area from bearing the costs of the ZLB, the truth is that the permanence of the ZLB in the euro area may be instead a consequence of the secular decline in natural real interest rates and thus regardless of the monetary policy framework. Hence, the permanence of the ZLB may not be a matter of monetary policy.

This dissertation is divided as follow. The next chapter reviews the most relevant literature on monetary policy frameworks and tries to figure out which one would be more suitable to address the ZLB. In so doing, it will first present the worldwide adopted inflation targeting, especially its three pillars and its contribution for the GM. It will also address the even more present issue of whether inflation targeting may have become a victim of its own success. A description of the GFC and how it paved the way to a permanent ZLB, as well as the emergence of unconventional tools, will be provided as well. And by acknowledging a secular decline in natural real interest rates, this chapter will finally expose alternative proposals to inflation targeting that may prove better suited to cope with the ZLB. In chapter 3, it will be simulated the adoption of price-level targeting by the ECB between the third quarter of 2009 and the fourth quarter of 2019. In so doing, this chapter will first expose the model to be employed. Then, it will present the data on all the variables of the model and address the estimation itself, whose parameter estimates will be used for simulating the adoption of an alternative regime. Finally, this chapter will not only describe the methodology used to address this simulation, as well as debate potential drawbacks and discuss the simulation results. Finally, chapter 4 concludes.

2 Monetary Policy Frameworks and the Zero Lower Bound: A Literature Review

This chapter aims at reviewing the most relevant literature on monetary policy frameworks and understanding which one would be more suitable to address the Zero Lower Bound (ZLB) on nominal interest rates. First, it will present the globally adopted inflation targeting and reflect upon its responsibility for the Great Moderation (GM), as well as its weakness to preclude the most advanced economies from bearing the costs of the persistent ZLB. Second, it will shed some light on the severity that portrayed the Global Financial Crisis (GFC) and how the ZLB has emerged and constrained the standard conduct of monetary policy. In this context, the implementation of unconventional monetary tools will be addressed as well. Third, acknowledging that the persistence of the ZLB may have turned into the new normal, this chapter also tries to understand whether there may have been any substantial change to the fundamentals, which by definition are not controlled by central bankers. Alternative proposals to the current inflation targeting that are thought to better deal with the ZLB will be then exposed at the end of the chapter.

2.1 Inflation Targeting

Inflation targeting was initially implemented in the 1990s and has become the monetary policy framework most adopted by central banks since then, including the European Central Bank (ECB) and the Federal Reserve. Given the prominence that policy frameworks will assume throughout this dissertation, this section is fully devoted to explaining the pillars on which inflation targeting has laid down, as well as clarifying how price stability – which was the noteworthy success of this regime – has been typically defined by countries that have embraced it.

2.1.1 Three Pillars: Numerical Target, Accountability, and Central Bank Independence

This subsection will then present the three main pillars of inflation targeting.

First of all, inflation targeting involves the public announcement of an explicit quantitative target for the inflation rate to be accomplished over the medium-to-long run. This means that central banks, in practice, need not worry about short-term divergences of observed inflation rates from the target.

A key *rationale* for this regime is that it promotes accountability of monetary policy. In short, accountability means the need to justify and acknowledge responsibility for decisions taken. Having this in mind, the announced inflation target allows economic agents to assess the performance of central banks, especially through the ex post observation of the temporal consistency of inflation rates with the assumed objective. There are then some mechanisms that assure accountability. For instance, in compliance with its Treaty, the ECB must report to the European Parliament, the Council of Ministers, and the Commission.

And for inflation targeting to be effective, central bank independence is commonly advocated in the literature. To put it simply, central bank independence refers to the autonomy of central bankers from direct political or governmental influence in the conduct of monetary policy. It is, indeed, of the utmost importance to preclude, for example, monetary policymakers from falling into the well-known time-inconsistency problem. Without independence, central banks could then be tempted to deploy overly expansionary monetary policy so as to obtain short-term gains in output and employment and therefore meet politicians' concerns about getting reelected. This would only be possible at the expense of accommodating actual inflation rates above the target, hence undermining the credibility of the regime (Bernanke & Mishkin, 1997; Issing, 1999; Mishkin & Posen, 1997; Svensson, 1997; Walsh, 2010).

After exposing these three pillars of inflation targeting, it is now possible to conclude that, by increasing transparency in monetary policymaking, it helps anchor inflation expectations in accordance with the target, thereby promoting price stability. In this regard, the next subsection will discuss how price stability has been usually defined, as well as try to figure out the reasons behind the worldwide adoption of 2 percent as the inflation target.

2.1.2 Price Stability

Price stability is nowadays the primary goal for most central banks under inflation targeting or at least is one among others. It is usually defined as low and stable inflation, and the most common numerical target for the inflation rate is around 2 percent. To give an example, the ECB aims at maintaining inflation rates below, but close to, 2 percent over the medium run.

Regarding the Federal Reserve, despite not being its exclusive objective[1], a formal inflation target of 2 percent has been also established since 2012[2].

Nevertheless, this raises a question about the *rationale* for the broad adoption of 2 percent as the inflation target. Albeit there is not any one-size-fits-all reason for this proceeding, since papers that try to estimate the optimal inflation target are all inevitably model-dependent (Billi & Kahn, 2008; Giannoni & Woodford, 2003), the truth is that 2 percent has been globally adopted essentially due to the following beliefs.

On the one hand, low and stable inflation has been advocated by a broad range of economists and policymakers, not only to support economic efficiency, but also to increase the living standards. For instance, according to Mishkin (2011), high and volatile inflation is not desirable because it may erode the store of value function of money, result in redistributions of wealth when inflation is higher than anticipated, and lead to overinvestment in the financial sector. It may also bring greater difficulty in planning the economic activity, as well as it may prompt a meaningful rise in the costs of borrowing because the higher the inflation, the more volatile it tends to be, hence increasing the inflation risk premium.

On the other hand, although an inflation target of zero percent may seem more tempting to avoid the problems mentioned above, there is a general agreement amongst central bankers to target a positive number for inflation. In this regard, Bernanke and Mishkin (1997) have pointed out three arguments. First, the price indexes that are commonly used to measure inflation tend to overestimate it, which means that an estimated inflation rate of zero percent is likely to hide a deflationary process. Second, given the observation by Akerlof, Dickens, and Perry (1996) that nominal wages are rigid downward, then a positive value for inflation expectations, which, in turn, arises from a positive inflation target, may be the only device available to reduce real wages when needed, for example, to increase the allocative efficiency in the labour market. Third, targeting a positive value for inflation is also crucial in order to prevent the economy from bearing the costs of deflation, such as the deferment of

---

[1] As mandated by the Congress in the Federal Reserve Act, the objectives of the central bank of the United States are not only promoting price stability, but also full employment.

[2] In practice, there was certainly an informal target of around 2 percent in the United States long before 2012, perhaps right after Alan Greenspan became president in the second half of the 1980s.

consumption and investment expenses, which would subsequently lead to a devasting decrease in aggregate demand.

Having explained the general guidelines of inflation targeting, time has come to reflect upon its performance as a monetary policy framework, which will be done throughout a new section.

2.2 The Performance of Inflation Targeting and the Great Moderation

As already noted, this section then aims at assessing the performance of inflation targeting since its initial adoption in the 1990s. After concluding that this regime was a tremendous success in reducing high and volatile inflation rates of the past, it will be discussed its decisive role for the GM. Finally, the third subsection gradually begins introducing the question under investigation of whether inflation targeting should have been replaced after the GFC so as to prevent the most advanced economies from encountering the ZLB. In this context, inflation targeting may have become a victim of its own success because the low inflation environment – its noteworthy success – reduces how further nominal interest rates can be lowered to produce a given decrease in real interest rates. And this even smaller cushion will no longer be available as soon as nominal interest rates reach their lower bounds.

2.2.1 The Success of Inflation Targeting

It is undeniable that the adoption of inflation targeting by a large number of central banks has managed not only to reduce and control high and volatile inflation rates of the 1970s and early 1980s, but also to anchor long-term inflation expectations at the corresponding inflation targets (Mertens & Williams, 2019; Walsh, 2009).

As Figure 1[3] shows, inflation rates in Canada, Germany, New Zealand, the United Kingdom, and G7 countries have substantially decreased towards levels close to 2 percent since the

[3] See Annexes.

adoption of inflation targeting[4]. Additionally, in Table 1[5], there is evidence that the implementation of inflation targeting has also succeeded in lowering the variability of inflation rates. Indeed, the years after the generalised adoption of inflation targeting have evidenced a sharp decrease in the standard deviation of inflation rates for all the countries mentioned above.

Finally, in what concerns to the anchoring of long-term inflation expectations, Figure 2[6] illustrates that 6-to-10-years-ahead inflation expectations have been very stable within a narrow band around 2 percent in a broad range of countries, especially since mid-1990s. This is clearly proof that inflation targeting[7] has produced well-anchored inflation expectations[8].

In another paper, Mishkin (2001) has come to the same conclusion. Inflation targeting has lowered inflation rates towards levels consistent with price stability, and they have remained under control since then. Moreover, given the well-anchored expectations, not only has price stability been much easier to attain over the medium or long run, but also the power of monetary policy to stabilise output and employment has increased in the short term[9], insofar as central banks need not worry that, for instance, a temporary monetary easing will produce rising inflation and inflation expectations. Although the disinflationary process after the oil

---

[4] New Zealand in 1990, Canada in 1991, and the United Kingdom in 1992 were the first countries to adopt inflation targeting. Although Germany's official monetary policy framework was monetary targeting, the German experience after the German monetary unification in 1990 was marked by the adoption of many elements of inflation targeting (Mishkin & Posen, 1997). That is the reason why Germany is on the list of the first countries to embrace inflation targeting. G7 countries, which were mentioned here to give a benchmark, are the world's seven largest advanced economies, including Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

[5] See Annexes.

[6] See Annexes.

[7] One needs to bear in mind that some countries plotted in Figure 2 did not officially adopt inflation targeting during the sample period, but they comprised many characteristics of this policy regime such as the focus on achieving and maintaining price stability over the medium-to-long run.

[8] In the words of Bernanke (2007), long-term inflation expectations are well anchored if they remain relatively insensitive to incoming data. This means that actual inflation rates may be temporarily either above or below the long-run expectations of inflation, but even so the public does not considerably adjust its forecasts.

[9] Since central bankers under inflation targeting are not deprived of the power to stabilise the real economy in the short term, some authors call this policy framework a flexible inflation targeting (Svensson, 2009).

crises of the 1970s and early 1980s was naturally associated with losses in output, another accomplishment of inflation targeting is that, once low and stable inflation has been achieved, output and employment have bounced back to the previous levels and output fluctuations have not significantly increased.

2.2.2 The Great Moderation

The success of inflation targeting in reducing inflation rates, as well as their volatility, can be translated into other words. Indeed, while there exist other reasonable explanations, including technological changes, for example, improved management of inventories (Cecchetti, Flores-Lagunes, & Krause, 2006; McConnell & Perez-Quiros, 2000), and the good-luck hypothesis based on the absence of major supply shocks (Ahmed, Levin, & Wilson, 2004; Stock & Watson, 2003), the worldwide adoption of inflation targeting may have decisively contributed to the GM[10] (Bernanke, 2004; Mojon, 2007; Pescatori, 2008). The role of this policy framework for the GM then mainly comes from allowing monetary policy to respond more vigorously to inflation and anchoring inflation expectations, which by themselves may act as a source of macroeconomic instability since they are able to influence interest rates and the real economy.

Undeniably, the GM was characterised by a remarkable decline in macroeconomic volatility across the most developed economies. For instance, Blanchard and Simon (2001) have documented, for the United States, that the variability of quarterly growth in real output had diminished by half since the mid-1980s, while the variability of quarterly inflation had fallen by about two thirds. Comparable declines in the volatility of both output and inflation have been found for most other G7 countries as well (Stock & Watson, 2003; P. M. Summers, 2005).

2.2.3 Has Inflation Targeting Become a Victim of its Own Success?

Notwithstanding the noteworthy accomplishment of inflation targeting during the GM, the well-known severity of the GFC[11] may have raised the question of whether this policy framework has become a victim of its own success. Indeed, the low inflation environment – a consequence of the adoption of inflation targeting – reduces how further nominal interest

[10] This period roughly began in 1984 and ended in 2007 with the emergence of the GFC.

[11] This topic will be further investigated in the next section.

rates can be lowered to generate a required decrease in real interest rates, which is especially restrictive when monetary policy is responding to severe negative shocks. The hypothesis that this regime may have become a victim of its own success has then gained particular attention in the most recent years because the undershooting of inflation targets within the developed world has exacerbated the low inflation environment (Gillitzer & Simon, 2015).

From now on, it seems to be of the utmost importance to understand whether inflation targeting, as it has been designed and put into practice, may have had any responsibility for the tough and protracted recovery from the GFC in the most advanced economies[12].

In so doing, I would consider it important to briefly describe what the GFC was about, explain how the conduct of monetary policy, particularly through the standard management of short-term nominal interest rates, has been constrained since then, and expose the economic recovery that followed the well-known financial crisis. In addition, it is also of the greatest interest to investigate whether there may have been any substantial changes to the fundamentals that may exempt monetary policy from having any direct responsibility for its lower effectiveness in managing the business cycle after the GFC.

And even if inflation targeting by itself may have not been responsible for the sluggish recovery, meaning that changes in fundamentals may have actually played its role, it might be particularly relevant either to trigger any modification within the current policy framework, or, if needed, exchange it by another regime that may prove more suitable to deal with severe economic recessions.

Keeping this in mind, the next section will embody a brief description of the GFC and the resulting ZLB. The purpose is not to be exhaustive, but only to shed some light on the topic in order to better understand their implications for the conduct of monetary policy, as well as to better comprehend the recovery from the crisis.

---

[12] One needs to bear in mind that the goal of this analysis is merely to understand whether inflation targeting may have contributed to the persistence of the severe recession that followed the GFC, rather than figure out whether this policy framework may have played its part in triggering the crisis itself.

2.3 The Global Financial Crisis and the Zero Lower Bound

The GFC, also known as the Great Recession, refers to the period between mid-2007 and early 2009 that was portrayed by a severe turmoil in worldwide financial markets and banking systems. This crisis started with the collapse of the housing market in the United States and rapidly spread to other countries, not only to those directly exposed to the American subprime mortgage market, but also to those that had developed their own imbalances in both credit and housing markets. In part related to the monetary policy tightening initiated by the Federal Reserve in 2005, asset prices, such as the prices of mortgage-backed securities, began to slump, hence triggering a large increase in asset sales and then an even more dramatic decline in their prices (Claessens, Dell'Ariccia, Igan, & Laeven, 2010; Leamer, 2015).

Once many banks across the globe faced considerable losses in their balance sheets, confidence concerns emerged, and banks significantly reduced the amount of credit issued to other financial institutions, non-financial companies, and households. That reduction alongside with the crash in stock markets affected not only the financial system, but also the real economy itself (Bordo, 2008).

Therefore, this section will try to explain first how the GFC evolved to a sovereign debt crisis in the euro area. Then, the emergence of the ZLB within the developed world will be discussed as well.

2.3.1 From the Global Financial Crisis to the Euro Area Sovereign Debt Crisis

The severity of the GFC was exacerbated in the euro area by the emergence of the European sovereign debt crisis around 2010. Indeed, as Lane (2012) has pointed out, the 2007-2009 financial crisis paved the way to a sovereign debt crisis in the euro area.

Due to the credit crunch mentioned above, the rise in nonperforming loans, and the instability in stock markets, the member states' governments, especially those already most affected by the GFC, were called upon to bail out some financial institutions, hence increasing its debt towards very high levels. This then led to rising sovereign risk premiums and downgrades in ratings of the most vulnerable countries, including Greece, Italy, and Portugal. Alongside with deteriorated ratings of financial system institutions, those economies were subject to an increase in spreads and, in turn, yields of both banks and fragile sovereigns climbed.

And since prices and yields are inversely proportional, then prices of the aforementioned government bonds decreased and banks' balance sheets with national bonds shrank. Therefore, the value of the available collateral of these banks also decreased, thereby reducing, on the one hand, the likelihood of obtaining credit in the interbank money market at reasonable interest rates and increasing, on the other hand, the need to be bailed out by the governments. In a nutshell, the GFC quickly evolved from a financial and banking crisis to an European sovereign debt crisis in a vicious circle (Draghi, 2019).

2.3.2 The Emergence of the Zero Lower Bound

This subsection will discuss the emergence of the ZLB on nominal interest rates.

In the context mentioned above, accommodative monetary policy was required in most of the advanced economies and the euro area was no exception. Given that the low inflation environment that inflation targeting typically assures was particularly exacerbated – at least temporarily – during the GFC, an even further decrease of nominal interest rates is needed to reduce real interest rates and thus stimulate both output and inflation.

As other central banks, in spite of adopting other less standard policies[13], the ECB also lowered its official interest rates. According to Figure 3[14], the ECB cut the interest rate on the main refinancing operations (MRO) to the then record low of 1 percent in May 2009. Thereafter, despite two consecutive increases of 25 basis points in April 2011 and July 2011, respectively, given the sovereign debt crisis mentioned above, the interest rate on the MRO was decreased again in November 2011 until it reached zero percent in March 2016, remaining unchanged since then (ECB, 2020b).

The ZLB[15] on nominal interest rates has then become a truly important challenge for the conduct of monetary policy by the ECB and other central banks such as the Federal Reserve

---

[13] See Cour-Thimann and Winkler (2012) for a more detailed analysis of the immediate ECB's monetary policy response to the GFC and the euro area sovereign debt crisis.

[14] See Annexes.

[15] More correctly, the effective lower bound because, although there is always the possibility of holding cash with a nominal return of zero percent instead of accepting negative nominal interest rates on savings, the storage and insurance of a large amount of cash have some costs that may allow nominal interest rates to be reduced further below zero (Beyer & Wieland, 2019).

and the Bank of England[16]. To the extent that these central banks have not managed to lower official interest rates further below zero or a small negative value, monetary policymakers have acknowledged their limited scope to reduce real interest rates through the standard monetary policy based on the management of short-term nominal interest rates.

In other words, the emergence of the ZLB and how it constrains the conventional monetary policy may provide support for the thesis that inflation targeting may have been victim of its own success. Therefore, although inflation targeting has succeeded in lowering high and volatile inflation rates of the past, the low inflation environment it has created may have significantly reduce or even exhausted the cushion of central banks to reduce official nominal interest rates when addressing deep economic recessions.

In order to overcome the ZLB constraint, many central banks across the globe have changed their *modus operandi* and engaged in unconventional monetary tools. The description of these measures will be held in the following section with particular emphasis on the euro area experience.

2.4 Implications for Monetary Policy: Unconventional Tools

Given that official nominal interest rates have reached the lower bound since the aftermath of the GFC, the traditional monetary policy response to severe economic downturns has become seriously constrained. Since the severity of this crisis has required a sharp easing of monetary conditions, most central banks in the developed world have implemented unconventional monetary tools in order to boost both output and inflation. The adoption of these measures was expected to be only temporary until the economies recovered from the damage caused by the crisis (Borio & Zabai, 2016).

In summary, Bernanke (2019) has divided them into four categories: quantitative easing, forward guidance, negative interest rates, and yield curve control. While quantitative easing and forward guidance have been embraced by a broader range of central banks, including the Federal Reserve, the ECB, the Bank of England, and the Bank of Japan, the adoption of

[16] In what concerns to the Japanese experience, unlike most other advanced economies, the ZLB has become seriously binding for more than twenty years (Williamson, 2019).

the other nonstandard measures has been narrower[17]. Indeed, from the range of central banks mentioned above, only European and Japanese monetary policymakers have implemented negative interest rates, and given the extraordinary Japanese experience, only the Bank of Japan has adopted yield curve control.

The next subsections will describe such unconventional tools in more detail, especially the differences between each and how they have been implemented in practice. A conclusion that will naturally emerge is that their effectiveness in easing monetary conditions can be boosted if they are complementarily embraced by central banks.

2.4.1 Quantitative Easing

Quantitative easing involves the purchase of a broad range of assets by central banks in the open market. As these operations are financed by the creation of bank reserves, central banks' balance sheets have then significantly increased. In practice, while the Federal Reserve has been allowed to acquire only Treasury securities and mortgage-related securities supplied by government-sponsored companies (Bernanke, 2019), other central banks, including the ECB, have been able, not only to buy a wide range of government bonds, but also an array of private sector securities, such as asset-backed securities, covered bonds, and corporate bonds (Draghi, 2019).

For instance, the Governing Council of the ECB decided to launch at its meeting on 22 January 2015 an expanded Asset Purchase Programme (APP) to give additional stimulus to the economy and thus provide the amount of policy accommodation needed to attain its price stability mandate. Although similar programs were deployed by the ECB in the first half of 2009, this marked the beginning of the quantitative easing in the euro area because it was when the magnitude of ECB purchases substantially rose.

As the ECB (2020a) has publicly announced, the aforementioned APP has consisted of the Corporate Sector Purchase Programme (CSPP), the Public Sector Purchase Programme (PSPP), the Asset-Backed Securities Purchase Programme (ABSPP), and the third Covered Bond Purchase Programme (CBPP3). Its implementation over time can be described as

[17] For example, as negative interest rates could lead to a destabilisation in the money market mutual funds, this is a pointed-out reason why the Federal Reserve has never turned negative its policy rates during the post-crisis period (Burke, Hilton, Judson, Lewis, & Skeie, 2010).

follows. Between March 2015 and December 2018, the Eurosystem carried out net purchases of securities under one or more of the programmes included in the expanded APP[18]. Later, net purchases were suspended between January 2019 and October 2019, meaning that the ECB fully reinvested the principal payments from maturing assets, but did not carry out cumulative purchases above the levels recorded at the end of December 2018. However, in the face of renewed fear of not achieving its price stability mandate, the ECB Governing Council decided on 12 September 2019 that net purchases would be restarted since November 2019 at a monthly average of €20 billion, expecting them to be in action as long as the key ECB interest rates are not raised.

In contrast with the slower response of the ECB, the Federal Reserve also engaged in Large-Scale Asset Purchases (LSAPs) between late 2008 and October 2014. There were three rounds of quantitative easing, during which the Federal Reserve's balance sheet increased from less than a trillion dollars to 4.5 trillion dollars. In practice, when LSAPs were carried out, the Fed acquired not only longer-term securities issued by the United States government, but also longer-term securities issued or guaranteed by government-sponsored agencies such as Fannie Mae or Freddie Mac (Bernanke, 2019; Kiley, 2018).

All in all, quantitative easing is expected to work through two main channels: the signaling channel and the portfolio balance channel. On the one hand, the former is related to the commitment of central banks to monetary easing, especially to maintaining policy rates low for longer (Bauer & Rudebusch, 2014). On the other hand, the latter departs from the premise that securities are not perfect substitutes in investors' portfolios[19], hence changes in the net demand of a security are able to affect asset prices and yields in general because central banks' purchases may induce investors to rebalance their portfolios (Bonis, Ihrig, & Wei, 2017). In summary, these two channels can be differentiated to the extent that the signaling channel acts by affecting expectations of future official rates, while the portfolio balance channel operates by changing term premiums.

---

[18] Monthly net purchases averaged €60 billion from March 2015 to March 2016, €80 billion from April 2016 to March 2017, €60 billion from April 2017 to December 2017, €30 billion from January 2018 to September 2018, and €15 billion from October 2018 to December 2018.

[19] This may occur as a result of differences in liquidity, transactions costs, information, regulatory restrictions, among others.

In this regard, Constâncio (2016) has stated that, for the particular experience of the euro area, quantitative easing has succeeded in providing additional monetary accommodation beyond the monetary easing through official rates, as well as in lowering several premia across a broad range of markets where the ECB has intervened.

2.4.2 Forward Guidance

Forward guidance, or the communication by central banks to the public about the expected or intended future conduct of monetary policy, has also been adopted in many jurisdictions. Its purpose has been to explain the policy reaction function of central banks to the public and reduce uncertainty and volatility in the markets, thereby affecting the longer-term interest rates (Constâncio, 2016).

As prices of longer-term financial assets depend, not only on the current policy rates, but also on their expected future path, central banks' forward guidance, which is intended to shape market expectations about the future path of monetary policy, can influence financial conditions today, even when the management of short-term policy rates is constrained by the zero lower bound (Guthrie & Wright, 2000). In so doing, forward guidance allows central banks to communicate their intention to maintain policy rates low for longer until the economies start to rebound in a sustained path, hence promoting monetary easing today.

Furthermore, forward guidance and quantitative easing can be understood as being complementary measures. While central banks' commitment to purchasing a broad range of assets aims at, not only reducing the term premiums, but also reinforcing the compromise that central banks will maintain policy rates low for longer, the management of expectations by central banks through forward guidance supports, in turn, the stimulus introduced by those purchases by preventing economic agents from expecting an increase in official rates. And according to Draghi (2019), this proves how fundamental forward guidance has been for the conduct of unconventional monetary policy in the euro area.

2.4.3 Negative Interest Rates

Negative interest rates have been implemented by the ECB and the Bank of Japan. In order to ensure the spread of negative rates to the interbank money market, these central banks charge a fee on the deposits that commercial banks make with them, and arbitrage guarantees that negative rates are also transmitted to other short-term money market interest rates (Bernanke, 2019).

As a result, negative interest rates enhance central banks with a new measure for lowering the longer-term interest rates, which are the ones that matter the most for investment decisions. In so doing, negative interest rates provide additional monetary accommodation under the ZLB by the fact that they are able to relax the nonnegative restraint on expectations of future short-term interest rates. Since central banks commit to an environment where short-term interest rates can be negative, the expectation that rates can only rise and never fall further when they reach zero percent is removed, thereby helping to lower longer-term interest rates. Furthermore, the portfolio balance channel through which quantitative easing operates is empowered by negative interest rates because commercial banks with high amounts of excess liquidity are encouraged to reduce their reserve holdings with central banks and hence expand their credit creation and acquire longer-term securities (Constâncio, 2016).

To give an example, the ECB has applied a negative interest rate on the deposit facility since June 2014[20]. Overall, Draghi (2019) has concluded that the implementation of negative interest rates in the euro area has succeeded in driving overnight rates into negative field, as well as in anchoring the short-to-medium-term branch of the yield curve. However, the benefits of this unconventional tool have been relatively modest because holding cash is an option that bounds how further below zero negative rates can be reduced.

2.4.4 Yield Curve Control

Yield curve control, or the direct management of longer-term interest rates, has been recently introduced by the Bank of Japan and comprises the targeting of yields on longer-term bonds. For instance, in a context of persistently low inflation, the Japanese monetary authorities are currently targeting the yield on 10-year government bonds at around zero percent (Belz & Wessel, 2019; Bernanke, 2019).

In practice, yield curve control is dual to quantitative easing. While central banks that adopt the latter set a target for asset purchases and let the market define the corresponding yields, monetary policymakers under yield curve control target the yield on one or more securities and then adjust the purchases in the amount needed to attain the predefined yield.

[20] The deposit facility rate is currently set at minus 50 basis points (ECB, 2020b).

After this comprehensive explanation of different sorts of nonstandard monetary measures, now is the time to pay attention throughout the next section to how the economic recovery from the GFC has taken place within the developed world.

2.5 The Economic Recovery from the Global Financial Crisis

The unconventional monetary policy response in the aftermath of the 2007-2009 financial crisis has been undeniably accommodative, hence signaling the commitment of central banks to promoting the economic recovery. As shown in Figure 4[21], this has translated into a sharp decline in short-term nominal interest rates in the United States, the United Kingdom, and the euro area since the outbreak of the crisis[22]. However, while they currently remain either close to zero in Japan or negative in the euro area, they gradually began to rise in the United States in 2015 and in the United Kingdom in 2017.

In this context, as an alternative to short-term nominal interest rates, some authors have estimated shadow interest rates trying to obtain a synthetic measure of the actual degree of accommodative policy during unconventional times (Krippner, 2013; Wu & Xia, 2016).

Additionally, it is evident in Figure 5[23] that not only have short-term nominal interest rates decreased in the most advanced economies, but also long-term ones. Nevertheless, the latter have faced a steadier downward trend, which, in turn, have started well ahead of the emergence of the GFC.

Given that the interest rates that are relevant to economic decisions are the real ones, it is then of the greatest interest to study them as well. As Figure 6[24] unveils, short-term real interest rates have turned negative in the United States, the United Kingdom, Japan, and the euro area during almost all the time that followed the well-known financial crisis. Long-term ones, plotted in Figure 7[25], have also evidenced a descending movement throughout all the

[21] See Annexes.

[22] Money market interest rates have also fallen in Japan since the aftermath of the GFC, but this decline has been smoother in comparison to the other advanced economies. Furthermore, they already reached historically low levels even before this crisis.

[23] See Annexes.

[24] See Annexes.

[25] See Annexes.

sample period. And they even reached values below zero percent during some intervals in the aftermath of the crisis.

Notwithstanding this unprecedent monetary easing, real Gross Domestic Product (GDP) has not recovered its pre-crisis trend in any of the advanced economies represented in Figure 8[26], even more than ten years after the outbreak of the GFC. Simultaneously, as disclosed in Figure 9[27], inflation rates in the United States, the United Kingdom, Japan, and the euro area have persistently remained below 2 percent during the same period, thereby exposing that the risk of deflation is not a chimera and that monetary policymakers must be aware of it.

Focusing now exclusively on the euro area experience, the outcome described above has led to the permanence of the ZLB in this monetary union with the MRO rate still set at zero percent. However, this constraint is likely to become more frequent henceforth[28]. To testify this claim, one needs to bear in mind that nominal interest rates that are agreed on when planning economic activity incorporate both inflation expectations and a required real interest rate.

On the one hand, there is evidence in Figure 10[29] that one-year-ahead inflation expectations noticeably dropped in the aftermath of the GFC and plunged even further after the European sovereign debt crisis. Furthermore, they have not bounced back towards levels relatively close to 2 percent yet[30]. However, the impact of the crisis on longer-term inflation expectations in the euro area has been quite reduced, hence meaning that the adjustment of one-year-ahead inflation expectations downwards may have played only a temporary role in constraining how further nominal interest rates could be lowered during the most recent years.

On the other hand, the finding of a secular decline in natural real interest rates may be nevertheless the primary factor explaining why the ZLB might embody an increasingly

---

[26] See Annexes.

[27] See Annexes.

[28] In practice, not only in the euro area, but also in the other advanced economies because the reasons why the ZLB may have become more frequent, as discussed later, are common to all the economies.

[29] See Annexes.

[30] This adjustment of inflation expectations downwards has been certainly caused by inflation rates undershooting the inflation target in the euro area.

binding constraint for the traditional conduct of monetary policy from now on. Given the attention this deserves, a more detailed analysis will be provided in the section that follows.

2.6 The Secular Decline in Natural Real Interest Rates

Natural real interest rates are usually defined as real interest rates consistent with actual real output equaling its potential level (Holston et al., 2017). They are of the utmost importance because they give a benchmark for evaluating the stance of monetary policy. From this perspective, monetary policy is expansionary in terms of output and inflation when actual real interest rates are below natural rates, and contractionary otherwise.

Having this in mind, it is now easier to understand why a declining tendency in natural real interest rates is able to increase the likelihood of an economy hitting the ZLB more frequently. In fact, the lower the natural real interest rates, the further the real interest rates need to be reduced so that monetary policy be accommodative. And by the fact that one-year-ahead inflation expectations, those that are relevant for economic decisions, have faced a slight slump below the inflation target during the most recent years, this means that the decrease in nominal interest rates required to promote a given drop in real interest rates is even larger. However, as already mentioned, nominal interest rates, including official interest rates, have a lower bound that restrains how further they can be lowered.

2.6.1 Estimates of Natural Real Interest Rates

Now is the time to look at the estimates of natural real interest rates and analyse whether they have actually faced a secular decline. Despite the well-known challenges regarding their measurement, especially because natural real interest rates are unobservable variables whose estimates are always subject to uncertainty and depend on econometric specifications or data series (Laubach & Williams, 2016), most authors have even so documented a clear downward trend in them.

Making use of the baseline specification of Laubach and Williams (2003), Beyer and Wieland (2019) have estimated a decrease in the equilibrium real interest rates in the United States since 1960s towards levels close to zero percent in the aftermath of the GFC[31]. In addition,

[31] See Figure 11 in Annexes. One needs to bear in mind that Beyer and Wieland (2019) have used a medium-run concept to describe equilibrium rates. These authors have also made a distinction between one-sided

Beyer and Wieland (2019) have also found a downward trend in the estimates of natural real interest rates in Germany, the euro area, and Japan from 1965 onwards[32]. However, three aspects are of particular relevance. First, estimates for Japan, both one-sided and two-sided, are lower than those for Germany and the euro area over the entire sample period. Second, estimates, especially one-sided, faced a sharp decline in Germany and the euro area right after the outbreak of the GFC, and turned even negative for the euro area and Japan. Third, estimates, both one-sided and two-sided, remain at low levels for all the economies, although they have slightly increased in the euro area roughly since 2013.

In another paper, in spite of using a different approach to the baseline model of Laubach and Williams (2003), Holston et al. (2017) have also estimated for the United States, Canada, the euro area, and the United Kingdom a large decline in natural real interest rates to historically low levels over the last 25 years[33]. These estimates share with the previous ones the dramatic decrease in the period that immediately followed the GFC, although these ones do not evidence a recent rebound in the euro area. On the contrary, estimates for this monetary union remain low and even negative in the most recent years of the estimation period.

2.6.2 Reasons Behind the Secular Decline in Natural Real Interest Rates

Having exposed some evidence that the developed world may have been facing a remarkable decline in natural real interest rates towards historically low levels, it is then of the utmost importance to figure out the reasons behind this new normal. In this regard, economists and policymakers have suggested the following. First of all, Holston et al. (2017) have stated that

---

estimates and two-sided estimates. The former refers to the estimation of unobservable variables, such as natural real interest rates, that is only based on past and current data. The latter uses the full dataset, including future data, in the process of estimating unobservable variables.

[32] See Figure 12 in Annexes. Once applying the baseline specification of Laubach and Williams (2003) to data for Germany, the euro area, and Japan conducts to estimates that are unstable and very sensitive to starting values, Beyer and Wieland (2019) have used the simplified estimation procedure from Garnier and Wilhelmsen (2009) to find more stable and more plausible estimates. However, one needs to take into account that these estimates remain very sensitive to the estimation period.

[33] See Figure 13 in Annexes. The downward trend of natural real interest rates has been coupled with a remarkable drop in the estimates of trend GDP growth.

a decline in the rate of potential output growth and a slowdown in trend productivity growth may have triggered a lower demand for investment and thus reduced equilibrium real rates of interest. Also contributing to the recent trend has been the mutable character of economic activity, where the leading technological enterprises of this age, such as Apple Inc. and Alphabet Inc., have managed to maintain an enormous market value with much less investment needs than its predecessors (L. H. Summers, 2014). Another factor, which has also been widely spread among researchers, is demographic changes. On the one hand, the upsurge in life expectancy has encouraged working age population to increase savings for retirement. On the other hand, slower population growth and lower fertility rates have reduced consumption and thus the demand for investment (Ferrero, Gross, & Neri, 2019). Overall, higher desired savings and less investment needs have simultaneously caused a decrease in natural real interest rates. A fourth one, pointed out by *e.g.* Bernanke (2005), is that a "global saving glut" has lowered equilibrium real rates of interest in the most advanced economies due to the increased propensity to save in emerging markets. This tendency, in turn, is associated with a higher demand for safe assets that are generally supplied by the most developed countries (Caballero, Farhi, & Gourinchas, 2017).

All in all, the secular decline in natural real interest rates may have meaningfully reduced the cushion of central banks to lower official nominal interest rates so that monetary policy be expansionary enough in the face of deep economic recessions. In other words, the ZLB may have turned today into a more pressing issue for monetary policymakers than in the past when natural real interest rates were estimated to be higher.

Against this backdrop, although it seems evident that the inability to have supported a quicker economic recovery cannot be fully ascribed to inflation targeting itself, the new environment of historically low natural real interest rates raises the legitimate question of whether inflation targeting framework, as it has been designed and put into practice, may have reached its expiration date. Indeed, the severity of the GFC may have called into question the effectiveness of that policy framework in addressing truly deep economic recessions.

To put it differently, the secular decline in natural real interest rates may require a new policy framework that proves better suited to deal with its consequences for the conduct of monetary policy, or at least entail some changes within the ongoing regime. Without

supporting any of them in particular, the next section will discuss some alternative proposals to the current inflation targeting that have gained increased attention in recent years.

2.7 Alternative Proposals to the Current Inflation Targeting

Acknowledging that the secular decline in natural real interest rates may have turned the ZLB into a more likely issue for the conduct of monetary policy henceforth, a broad range of economists and policymakers have suggested alternative proposals to the current inflation targeting in order to enhance the potency of central banks facing such constraint (Bernanke, 2019; Bernanke et al., 2019; Constâncio, 2017; Eggertsson & Woodford, 2003; Mertens & Williams, 2019; Mester, 2018).

Four of these alternatives will be debated throughout the following subsections. In particular, it will be reviewed economic literature on how they would be better suited to deal with the ZLB, as well as presented the main advantages and disadvantages each would have[34].

2.7.1 Raising the Inflation Target

As long as official nominal interest rates in the long run roughly equals to the inflation target plus the natural real interest rate, and given the assumption that monetary policy is not able to affect real variables within that period, one possibility to enhance the cushion of central banks facing an increasingly binding ZLB constraint would be to raise the inflation target.

In this regard, by advocating that 2 percent inflation target may be too low, some researchers have suggested increasing it towards 4 percent (Ball, 2014; Blanchard, Dell'Ariccia, & Mauro, 2010). After a transitional period, which will naturally be shorter the more credible the announcement is, a higher inflation target would raise both inflation expectations and nominal interest rates, hence reducing the likelihood of conventional monetary policy being constrained by the ZLB. This would then provide more room to cuts in official nominal interest rates when needed, for instance, to address deep economic recessions.

An important advantage of this proposal is certainly the easy communication. Indeed, monetary policymakers can easily communicate the new inflation target to the public because the inflation targeting itself would be preserved.

---

[34] There would be of course other alternatives, such as fiscal policies focused on to stimulate both trend GDP growth rates and natural real interest rates.

Nevertheless, there are also crucial drawbacks that should not be neglected. First of all, according to Bernanke (2019), since inflation expectations seem to be well anchored near 2 percent in advanced economies, the process of re-anchoring inflation expectations at a higher level might be extended and ambiguous, and is likely to trigger financial instability and upturns in risk premia.

Another concern is related to the commitment of central banks to that new target. Indeed, as Blanchard et al. (2010) have recognised, if central banks decide to raise the inflation target, this might undermine their credibility with the public because there would be no guarantee that monetary policymakers will not increase the target again in the future as a response to other challenges.

Moreover, although the following argument seems unpersuasive for economists, raising inflation rates in the future might be very unpopular with the public due to, for example, various forms of money illusion (Bernanke, 2019).

Last but not least, some theoretical research has found that an increase in the inflation target is not an optimal response to address the ZLB (Eggertsson & Woodford, 2003; Krugman, 1998; Werning, 2011). First, as Woodford (2009) has stated, the strategy mentioned above compels the economy to face the costs of higher inflation at all times. Second, a one-time rise of the inflation target may not be enough to calibrate the accuracy of the monetary policy response to the severity and duration of a given ZLB episode. Rather, the theoretically optimal response is for central banks to commit to adopting "makeup" policies – or "history-dependent" policies in the words of Eggertsson and Woodford (2003).

Three branches of "makeup" policies will therefore be debated in the following three subsections. Even though details differ, they broadly encompass the commitment of central banks to maintaining policy nominal interest rates lower for longer when the ZLB binds (Bernanke et al., 2019).

2.7.2 Price-Level Targeting

Price-level targeting has been advocated by a broad range of economists and policymakers as a more suitable policy framework to enhance monetary policy response to ZLB episodes (Bernanke, 2019; Carlstrom & Pescatori, 2009; Gaspar, Smets, & Vestin, 2010; Williams, 2017). Therefore, it would be of the greatest interest to explain not only how it would work in practice, but also how it would be better suited to address the ZLB.

While a central bank that adopts inflation targeting aims at maintaining inflation in a stationary trend around its target, the goal of a central bank under price-level targeting is to keep the level of prices on the announced target path. Actually, if a central bank pursues a price-level target, it must commit to stimulating higher-than-target inflation in the future when a temporary shock causes lower-than-target inflation, and vice-versa[35]. This is obviously imperative for allowing the return of the price level towards its target.

The main difference between the policy frameworks mentioned above is then the treatment of bygones. Under inflation targeting, there is no effort to reverse past divergences from the target and the goal is barely to bring inflation back to its target. Instead, a central bank fully committed to price-level targeting must reverse temporary shocks that cause a differential between actual inflation and the implicit inflation target in the price-level target.

The effectiveness of price-level targeting heavily depends on inflation expectations. Under this framework, for example, if a deflationary or disinflationary shock hits the economy when nominal interest rates are close to zero, economic agents know that the central bank must generate above-target inflation in the future so as to ensure that the price level goes back to its target. This causes an upsurge in expected inflation, hence reducing real interest rates and, in turn, stimulating both real economy and inflation.

Accordingly, Gaspar et al. (2010) have concluded that inflation expectations have a fundamental role as automatic stabilisers within price-level targeting. The mechanism through which inflation expectations are created, whether more backward-looking or more forward-looking, is thus crucial. In accordance with how price-level targeting works, the more forward-looking the inflation expectations' formation process, the more effective this framework will be, especially in overcoming deep economic recessions when policy rates reach the lower bound. Hence, for an eventual adoption of this framework to be effective, central banks should firstly guarantee that inflation expectations are mainly grounded on forward-looking components.

---

[35] One needs to bear in mind that a price-level targeting central bank would not have a direct inflation target. However, we mentioned an inflation target when we referred to price-level targeting because it is actually implicit in the price-level target an inflation target.

The transition from the current inflation targeting to price-level targeting might have the following benefits. First, according to Bernanke (2019), this alternative framework is compatible with the price stability mandate because it allows low average inflation (say, 2 percent) over the years.

Second, Kahn (2009) has stated that, although inflation targeting has managed to stabilise inflation rates, price-level targeting would reduce uncertainty about the price level in the future. Simultaneously, this economist has advocated that this alternative policy regime is likely to produce greater stability in both output and inflation.

Third, as Bernanke (2019) and Brainard (2019) have pointed out, price-level targeting has the desirable "makeup" feature that is advocated by the theoretically optimal monetary policy. Particularly when the ZLB is binding, central banks under this framework must commit to reversing periods of below-target inflation by triggering above-target inflation in the future, thereby allowing policy rates to maintain lower for a longer period relatively to what would happen under inflation targeting. In this context, Williams (2017) have stated that the aforementioned "makeup" feature ensures that inflation follows, in average over the medium run, an underlying target on the targeted path for the price level, regardless of the limited knowledge about natural interest rates that policymakers typically have.

Fourth, Cole (2018) has claimed that central banks can boost the benefits of forward guidance by adopting price-level targeting instead of inflation targeting. Indeed, under the former, not only does forward guidance lead to higher values of output and inflation, but also lower welfare losses – measured by variances of inflation, output, and interest rates.

However, price-level targeting is not without its shortcomings. First, Bernanke (2019) has acknowledged that a change to an entirely new monetary policy framework with a new reaction function might be an enormous challenge[36]. For instance, the adjustment to the implications of price-level targeting by economic agents, especially in terms of inflation expectations, is likely to be a very protracted process.

Second, this alternative framework might not be well suited to deal with temporary supply shocks that cause above-target inflation (Bernanke, 2019; Carlstrom & Pescatori, 2009). In

[36] This framework has never been tested in practice, except for a short period in Sweden in the 1930s after leaving the gold standard in 1931 (Kahn, 2009).

case they happen, central banks must commit to lowering inflation below the target in the future by triggering an increase in real interest rates. Naturally, this commitment might not be credible because it implies a costly monetary tightening, which assumes particular relevance when supply shocks are associated with severe impacts on output and employment.

Third, IMF (2013) has recognised that the benefits of price-level targeting may disappear if inflation is not very responsive to economic slack. This is, indeed, a serious challenge for this alternative policy framework because the short-term Phillips curve seems to have flattened as noted by Svensson (2020) . However, if the inflation expectations channel works well, this may mitigate the problem.

2.7.3 Temporary Price-Level Targeting

Looking for a compromise approach, Bernanke (2019) has proposed temporary price-level targeting that consists in adopting price-level targeting as described above only during periods when the ZLB constraint binds, and preserving inflation targeting with the current inflation target otherwise[37]. Under this policy framework, central banks would communicate to the public that, when policy nominal interest rates reached the lower bound and inflation was below target, they would follow a price-level target, instead of an inflation target. In so doing, they would commit to reversing episodes of inflation below the target by causing periods of inflation above the target in the future, thereby increasing inflation expectations and diminishing real interest rates.

Such commitment would give an important stimulus to an economy facing the ZLB because, under this proposal, the eventual raise in official nominal interest rates would be postponed until the average inflation during the entire period of the ZLB constraint had reached at least the inflation target. Equivalently, the necessary condition for raising official rates could be explained in terms of price level. Indeed, that condition would be that price level had returned to its target path, thereby implying a period of inflation above the underlying inflation target. And once price level converged to its target, monetary policymakers would revert to inflation targeting.

[37] Evans (2012) had already suggested a similar approach.

Compared to the ordinary price-level targeting, this alternative might have two crucial advantages. First, as pointed out by Bernanke (2019), temporary price-level targeting would not require a major adjustment to the current inflation targeting framework because it would continue to operate away from the ZLB. Second, temporary price-level targeting would also avoid the need to reverse temporary inflation shocks at times when the economy is away from the ZLB, times when monetary tightening would occur if central banks adopted price-level targeting.

However, a drawback against this proposal may be the enormous complexity when it comes to decide the precise moment when policymakers must switch from price-level targeting back to inflation targeting. Indeed, central bankers would need to guarantee that low inflation during the ZLB episode had sustainably been made up for, albeit this may induce undesired discretion that is likely to undermine the credibility needed for the success of this policy framework (Mester, 2018). Also, real-time data issues might emerge.

To sum up, Bernanke (2019) claims that temporary price-level targeting could be an effective alternative to reduce not only the duration and the severity of the ZLB on nominal interest rates, but also the frequency of this constraint. The author argues that if this policy regime had been implemented before the GFC and correctly understood by economic agents, then longer-term interest rates would likely have been lower, and thus the actual degree of monetary policy accommodation could have been greater during the period after the crisis. In other words, inflation could have been higher, and policy nominal interest rates would likely have increased towards levels significantly away from the ZLB.

2.7.4 Nominal GDP Targeting

Other authors have proposed the adoption of nominal GDP targeting. This framework consists in establishing a target for the level of nominal GDP and conducting monetary policy accordingly so that the actual level does not deviate considerably from that target. This is not new since McCallum (1987, 1988) had already come up this idea in the 1980s.

Nominal GDP targeting is similar to price-level targeting insofar as monetary policymakers are committed to pursuing the level of nominal GDP, rather than the growth rate. In so doing, central banks also aim at making up for past deviations, hence the need to trigger either an overshoot or an undershoot of the nominal GDP growth rate as a response to temporary shocks that decrease the level of nominal GDP below the target or increase it above, respectively.

Fackler and McMillin (2020) have advocated that targeting the path for nominal GDP may be not only preferable to inflation targeting, but also more suitable than targeting the path for the price level. In fact, they have simulated that nominal GDP targeting based on a 4.5 percent growth rate would have produced higher welfare from the first quarter of 2004 to the fourth quarter of 2006 in the United States. To understand why nominal GDP targeting may be even superior to price-level targeting, Fackler and McMillin (2019) would consider of the utmost importance to firstly reflect on the different type of shocks, especially the negative ones, that are likely to hit the economy, as well as how monetary policymakers usually address them.

As we well know, shocks can emerge either from the demand side of the economy or the supply side. In this particular point, it is fundamental to distinguish between both.

On the one hand, when a negative aggregate demand shock hits the economy, for example, a generalised breach in investor confidence, both real output and inflation tend to decrease. Central banks generally reduce policy nominal interest rates – or engage, as recently, in unconventional measures such as quantitative easing and forward guidance – in order to stimulate aggregate demand and promote the return of inflation rate to its target. As described before, history-dependent policies that target the level, rather than the growth rate, make up for deviations from the target, which may lead to faster economic recoveries after a severe economic recession in comparison with inflation targeting. There is no major difference in terms of effectiveness in dealing with negative shocks from the demand side has the central bank adopted nominal GDP targeting or price-level targeting.

On the other hand, if a negative aggregate shock from the supply side buffets the economy, for instance, a sharp increase in the relative price of oil, monetary policymakers face a dilemma because inflation moves upwards and real output downwards. As a consequence, the reaction of central banks may vary in accordance with their preference to stabilise the output gap or the inflation rate. Considering a central bank under inflation or price-level targeting that is relatively more responsive to deviations of inflation from the target, a restrictive monetary policy will emerge in order to reduce inflation, but the fall in real output will be amplified. Nonetheless, the monetary policy will be more severe under price-level targeting rather than inflation targeting due to the "makeup" feature of the former. Otherwise, when central banks target the level of nominal GDP, as long as nominal GDP encompasses real GDP and inflation, there may not be the need to pursue neither a

contractionary nor an expansionary policy in the special case in which the upsurge in inflation exactly offsets the drop in real output. Even when inflation increases relatively more than real output falls, hence raising the level of nominal GDP above the target path, monetary policy will be less restrictive compared with inflation or price-level targeting because the upsurge in inflation is partially compensated by the decrease in real output. And if real output decreases relatively more than the rise in inflation, policymakers will ease monetary conditions to ensure the return of nominal GDP to the target. Therefore, one can easily conclude that nominal GDP targeting is more stabilising than inflation or price-level targeting in the face of aggregate supply shocks.

Nevertheless, one also needs to bear in mind that supply shocks mentioned above were expected to be only temporary. This is important because the response of nominal GDP targeting central banks to permanent shocks that lower the output growth rate in the long run must be different. Underneath this scenario, if monetary policymakers want to avoid a permanent inflationary process needed to preserve nominal GDP along with the pre-shock level, the target path for the nominal GDP must be adjusted downwards so as to be compatible with a slower potential growth. However, in the face of such a permanent productivity shock, central banks under inflation or price-level targeting will not need to change their inflation target or their objective for the price level.

Albeit using different models, other economists have also demonstrated the superiority of nominal GDP targeting. Garín, Lester, and Sims (2016) have found that this framework outperforms inflation targeting when wages are sticky relative to prices. Their conclusion is connected with research done by Gorodnichenko and Shapiro (2007) and Giannoni (2014) who have stated that price-level targeting would be more suitable than inflation targeting. In fact, as Garín et al. (2016) have discussed, targeting the level of nominal GDP is equivalent to targeting the price level in the long run because the long-term level of real GDP is not determined by monetary conditions. However, these authors have additionally concluded that nominal GDP targeting may be more flexible than price-level targeting in the short-term since the former allows divergences of both real output and price level from their long-term implicit targets. This flexibility is of the utmost importance under a model in which prices and wages are sticky. Beckworth and Hendrickson (2020) have advocated the preeminence of nominal GDP targeting as well.

Their main argument is that this framework would not require as much knowledge as inflation targeting does. For instance, central banks under nominal GDP targeting would not need to concern about estimates of potential output. In this regard, since forecast errors of the output gap by the Fed can weigh about 13 percent of the fluctuations in the output gap, Beckworth and Hendrickson (2020) have simulated that nominal GDP is likely to generate lower variability in the output gap and inflation relatively to the standard Taylor rule under imperfect information. By avoiding the need to have an estimate of natural output, that is, the need to compute the output gap – which inflation targeting requires – this is therefore an important advantage of nominal GDP targeting over other regimes (McCallum, 1999).

Nonetheless, nominal GDP targeting also faces important challenges. First, according to IMF (2013), central banks would need to compute nominal GDP in real time, although this measure may be subject to revisions, some of them with long lags. Second, any sort of excessive optimism of central bankers about the prospects for real GDP may trigger higher inflation, hence threatening the anchoring of inflation expectations.

3 Inflation Targeting vs. Price-Level Targeting: A Contrafactual Analysis for the Euro Area

The secular decline in natural real interest rates in the most advanced economies, including the euro area, may have increased the likelihood of the ZLB being more frequently binding. The traditional conduct of monetary policy, especially during negative shocks to the economy, might then become severely constrained most of the time henceforth. As mentioned above, some economists and policymakers have suggested alternative proposals to inflation targeting so as to overcome such constraint.

Among those proposals, this dissertation has given particular attention to price-level targeting mainly due to the role that inflation expectations play as automatic stabilisers and because price-level targeting may become easily understood by rational agents.

In this context, despite all the struggles in implementing such a change within the euro area[38], this dissertation aims at investigating whether the timely adoption of price-level targeting would have prevented the euro area from encountering the ZLB or at least would have reduced the duration and the severity that this constraint has embodied since the GFC. To do so, we will try to simulate the 2009Q3-2019Q4 path of inflation expectations, inflation rates, output gap, and short-term nominal interest rates, if the ECB had decided to change from the current inflation targeting to a price-level targeting regime.

All in all, the purpose of this chapter is to embrace a counterfactual analysis by comparing the simulated evolution of those variables to their observed values. In so doing, this dissertation will try to assess whether the permanence of the ZLB in the euro area may have resulted from the fact that inflation targeting has become a victim of its own past success, and thus being a matter of monetary policy framework, or whether it should be assigned rather to fundamental changes, especially a decline in natural real interest rates.

This chapter is then divided as follows. First, a description of the theoretical model that will be used throughout the chapter is presented. Given that the counterfactual analysis

[38] As derived from Cour-Thimann and Winkler (2012), these struggles naturally arises from the institutional setup in which the euro area is based on since it is a multi-country area where policy framework changes require approval by a broad range of heterogeneous countries.

mentioned above will require estimates of model parameters, the second section of this chapter will address the estimation needed by first exposing the data on all the variables needed, both endogenous and exogenous, presenting the estimation method, and then discussing the estimation results themselves. Finally, this chapter will not only explain the methodology that will be used to simulate the adoption of price-level targeting, but also debate the simulation results.

3.1 The Model

This dissertation makes use of a standard New Keynesian model formulated in discrete time as done by Mertens and Williams (2019) and described, for instance, in Clarida, Galí, and Gertler (1999). The model comprises three equations describing the behaviour of three endogenous variables: the inflation rate, π_t, the output gap, x_t, and the short-term nominal interest rate, i_t.

A forward-looking Phillips curve determines inflation as a function of expected future inflation, $\mathbb{E}_t\pi_{t+1}$, the output gap, and a supply shock, μ_t, according to the following specification:

$$(3.1)\ \pi_t = \beta\mathbb{E}_t\pi_{t+1} + \kappa x_t + \mu_t,$$

where $\mathbb{E}_t$ designates expectations grounded on information at time t, β and κ are expected to be greater than zero, and supply shocks are assumed to be uniformly distributed over time and independent from each other.

The output gap is measured by a forward-looking IS curve that relates the output gap to the expected future output gap, $\mathbb{E}_t x_{t+1}$, the differential between the ex-ante real interest rate and the natural real interest rate, $i_t - \mathbb{E}_t\pi_{t+1} - r_t^*$, and a demand shock, ϵ_t:

$$(3.2)\ x_t = \theta\mathbb{E}_t x_{t+1} + \alpha(i_t - \mathbb{E}_t\pi_{t+1} - r_t^*) + \epsilon_t,$$

where θ is expected to have a positive value, α a negative one, and demand shocks are assumed to be uniformly distributed over time and independent from each other[39].

[39] Unlike Clarida et al. (1999) and Mertens and Williams (2019), this dissertation allows θ to be different from 1.

Regarding the determination of the short-term nominal interest rate, this dissertation applies a different approach from that used in Mertens and Williams (2019). Instead of deriving the monetary policy rule from the minimisation of the expected central bank's loss function, short-term nominal interest rate is assumed to be set in agreement with the standard Taylor (1993) rule as follows:

$$(3.3)\ i_t = r^* + \mathbb{E}_t\pi_{t+1} + \lambda(\pi_t - \pi^T) + \gamma x_t + \nu_t,$$

where λ is expected to be greater than 1[40] and γ greater than zero – so that monetary policy is stabilising – and ν_t represents non-systematic policy and introduces randomness into equation (3.3). The component $\mathbb{E}_t\pi_{t+1}$ is a forward-looking variable that replaces either the last period's inflation rate, as is very common in the literature, or the inflation target, π^T, as *e.g.* in Clarida, Galí, and Gertler (2000).

In order to obtain estimates for the model parameters, the next section of this chapter will cope with the estimation of the model for the euro area.

3.2 Estimation of the Model for the Euro Area

Given that estimates of model coefficients are required for the simulation of the adoption of price-level targeting, this section will address the estimation methodology applied. In so doing, it will first describe the data on all the variables for the euro area from the first quarter of 1999 to the fourth quarter of 2019. Then, it will present the estimation method and discuss the estimation results.

3.2.1 Data

Our standard New Keynesian model will be estimated with quarterly data for the euro area between the first quarter of 1999 and the fourth quarter of 2019. As derived from the specifications of equations (3.1), (3.2), and (3.3), data within the aforementioned sample period will be needed for the following variables: inflation rates, output gap, short-term

[40] Given the Taylor principle, an increase of 1 percentage point of the expected inflation rate above the inflation target requires a higher-than-1 rise in the short-term nominal interest rate so as to generate an effective upsurge in the ex-ante real interest rate, and vice versa.

nominal interest rates, inflation expectations, output gap expectations, and natural real interest rates[41].

Before the estimation itself, the goal of this part of the dissertation is not only to briefly explain how the data for the aforementioned variables were obtained, but also to describe their evolution from 1999Q1 to 2019Q4. The first three variables to be presented are endogenous to the model and the remaining are exogenous.

3.2.1.1 Inflation Rates

Inflation rates are measured by the quarterly annual (year on year) rate of change of the harmonised index of consumer prices (HICP). Data were retrieved from Eurostat at a monthly frequency, where the value for each month is the change in percent relative to the same month in the previous year. These data were then converted to a quarterly base by averaging monthly inflation rates for each quarter.

As shown in Figure 14[42], the euro area inflation rate has registered quite different behavior in specific periods since 1999Q1 until 2019Q4. Before the emergence of the GFC, inflation rates have been relatively stable at levels between 2 and 3 percent until they have reached a peak at 3.9 percent in the third quarter of 2008. After the 2007-2009 financial crisis, inflation rates have fallen considerably and reached even a negative value of minus 0.3 percent in the third quarter of 2009. Inflation rates have recovered thereafter and reached almost 3 percent during 2011. With the euro area sovereign debt crisis, inflation rates have considerably plunged again and after 2016Q3 they began to converge to the goal of the ECB of 2 percent, although in the most recent quarters with a slight downward bias.

3.2.1.2 Output Gap

The output gap measures whether a country records a level of real economic activity above or below trend. Data for this endogenous variable in the euro area were not directly obtained from any source. Rather, they were constructed as follows:

---

[41] The inflation target under the current inflation targeting framework, which is needed in equation (3.3), is assumed to be equal to two percent throughout all the sample period, although the actual objective of the ECB is to keep inflation rates below, but close to, 2 percent over the medium run.

[42] See Annexes.

$$(3.4)\ x_t = 100 * (y_t - y_t^*),$$

where y_t is the natural logarithm of quarterly actual real GDP and y_t^* is the natural logarithm of quarterly potential real GDP.

Quarterly data for actual real GDP were directly retrieved from Eurostat and comprises seasonally and calendar adjusted data where 2015 works as the base year. Quarterly data on potential real GDP were obtained by interpolating annual data available at AMECO database from 1999[43] to 2019[44] through the Chow-Lin interpolation method. This method assures that the sum of the quarterly interpolated values equals the annual values.

Both time series of actual real GDP and potential real GDP were subject to a natural logarithmic transformation and then the difference between both for each t were computed. This procedure yielded a quarterly time series for the output gap[45].

Figure 15[46] shows the euro area output gap between the first quarter of 1999 and the fourth quarter of 2019. This variable was typically positive before the GFC with a peak in 2001Q1 and another in 2008Q1, meaning the favourable economic conjuncture during those times. With the emergence of the GFC, it turned negative until 2017Q1. In the most recent years, the output gap has been fairly stable at around 1 percent, which is a signal of a timid and protracted recovery.

3.2.1.3 Short-Term Nominal Interest Rates

In order to unveil the stance of monetary policy in the euro area from 1999Q1 to 2019Q4, data on short-term nominal interest rates were needed. One possibility could be the Euro Overnight Index Average (EONIA). However, given the ZLB on official nominal interest rates and the emergence of unconventional monetary policy tools in the aftermath of the GFC, shadow interest rates have recently gained attention as indicators of monetary policy,

---

[43] Data on potential real GDP for 1999 was not available at the AMECO database for the 19 countries euro area, and so it was assumed that it evolved similarly to the 12 countries euro area time series.

[44] As it will be clearer when describing the creation of estimates for output gap expectations, annual data that was interpolated to obtain quarterly data was in practice from 1999 to 2020.

[45] The multiplication by 100 in equation (3.4) only serves the purpose of obtaining percentage values for the output gap.

[46] See Annexes.

as they allow for comprising all the information about conventional and unconventional monetary policy in a single time series.

This dissertation makes use of the new shadow interest rates estimates, computed by Krippner (2013) for the euro area, as a proxy for the short-term nominal interest rates. These estimates are from the May 2020 version of the author's model and concern to the August 2020 update. They contrast with the old ones that were obtained by using the 2016 author's model, whose last available update was made in April 2020. Both new and old shadow interest rates estimates were converted from monthly to quarterly data and are plotted in Figure 16[47] for comparison purposes. Additionally, Figure 16 also includes data on EONIA that were converted from a daily to a quarterly basis.

Figure 16 shows that both the new and old shadow interest rates estimates were not considerably different from EONIA before the ZLB became binding and the emergence of unconventional measures. Thereafter, EONIA has been recently stable at relatively small negative values close to zero percent, while shadow interest rates have decreased considerably towards more negative values – especially old shadow interest rates that have assumed even more negative values than new ones. A common feature of all the proxies for the short-term nominal interest rates has been their considerable downward trend, especially since the GFC.

3.2.1.4 Inflation Expectations

Expected inflation is one of the most prominent exogenous variables for the model. It pays a crucial role in the assessment of the impact of price-level targeting on the endogenous variables.

In practice, data for this variable – generated under the current policy framework – were retrieved from the ECB Survey of Professional Forecasters (SPF) and correspond to the expected inflation one year ahead[48].

[47] See Annexes.

[48] Although the model formulation itself concerns to the expected inflation for the following quarter, this dissertation uses in practice the one-year-ahead expected inflation.

In what concerns its evolution over time within the euro area, there is evidence in Figure 17[49] of a relatively well anchoring of inflation expectations around the objective of the ECB until the beginning of the 2007-2009 financial crisis. After that – and all the more exacerbated following the sovereign debt crisis – short-term inflation expectations in the monetary union have faced a downward trend, and reached less than 1 percent in the first quarter of 2015. More recently, expected future inflation was slowly recovering towards the ECB's policy target until it declined again from 2018Q4 onwards.

3.2.1.5 Output Gap Expectations

Data on this exogenous variable were not directly retrieved from any source, and were created as follows:

$$(3.5)\ \mathbb{E}_t x_{t+1} = 100 * (\mathrm{E}_t y_{t+1} - \mathrm{E}_t y^*_{t+1}),$$

where $\mathrm{E}_t y_{t+1}$ is the expected natural logarithm of quarterly actual real GDP and $\mathrm{E}_t y^*_{t+1}$ is the expected natural logarithm of quarterly potential real GDP. Given that data on real GDP growth forecasts is available at the ECB's SPF, $\mathrm{E}_t y_{t+1}$ is measured according to the following specification:

$$(3.6)\ \mathrm{E}_t y_{t+1} = y_t + g^E_t/100,$$

where g^E_t is the one-year-ahead expected real GDP growth rate in the SPF. In short, taking the forecasts for real GDP growth rates and actual data on real GDP, both available at each period, we then compute the level of future expected real GDP[50].

Expected real GDP is needed to obtain estimates for the output gap expectations, but also to obtain data on expected potential real GDP. For simplification, and assuming perfect foresight, this dissertation makes use of the potential real GDP observed in the next year as proxy for the expectation of potential real GDP made today, as follows:

$$(3.7)\ \mathrm{E}_t y^*_{t+1} = y^*_{t+1}.$$

---

[49] See Annexes.

[50] Although the model formulation itself concerns to the expected output gap for the following quarter, this dissertation uses in practice the one-year-ahead expected output gap.

After explaining how values for this variable were generated, a brief description about their evolution over time is now provided. Figure 18[51] indicates that output gap expectations are quite aligned with the output gap estimates, in the euro area from 1999Q1 to 2019Q4. In short, output gap expectations were positive most of the time before the emergence of the GFC until they turned negative thereafter. More recently, values for this variable have recovered towards positive values since 2017Q1.

3.2.1.6 Natural Real Interest Rates

The estimates of natural real interest rates are those calculated by Holston et al. (2017). The estimates that we use are one-sided and correspond to the 2020Q1 update.

The evolution of this variable in the euro area was already described above, but Figure 19[52] includes a more recent sample period – until the fourth quarter of 2019. In short, data on this variable shows a significant downward trend of the natural real interest rate from 2000 through 2014, and rather stable levels thereafter.

Table 2[53] summarises the data used in the present work.

3.2.2 Methodology

Having presented the model and described the data, and before discussing the estimation results themselves, we now explain the estimation methodology.

Making use of data available for the euro area from the first quarter of 1999 to the fourth quarter of 2019, which comprise 84 observations for each variable, this dissertation estimates the system of three linear stochastic equations composed of (3.1), (3.2), and (3.3). We aim at estimating coefficients β, κ, θ, α, λ, and γ under the current inflation targeting policy framework. Given that price-level targeting has never been implemented in the euro area, those estimates are taken as the benchmark for our exercise of describing the relationships between the endogenous and exogenous variables of the model; specifically, those estimates will be used to simulate the effects of the adoption of an alternative monetary policy regime throughout next section.

---

[51] See Annexes.

[52] See Annexes.

[53] See Annexes.

The estimation method employed is Full Information Maximum Likelihood (FIML), which is a consistent method to estimate a model of simultaneous linear stochastic equations. It draws on the maximisation of a likelihood function and assumes that the contemporaneous errors follow a joint normal distribution. Under FIML, coefficient estimates are derived from the estimation of the system as a whole instead of the estimation of each equation independently. Hence, FIML takes into account, not only information related to a specific equation alone, but also pertaining to other equations, and considers that the structural disturbances of all the equations are contemporaneously correlated. As a result, FIML leads to asymptotic efficiency[54].

3.2.3 Estimation Results

In the left panel of Table 3[55] we report the parameter estimates and the corresponding p-values, for the whole sample period (1999Q1-2019Q4). First, the p-values tell that all the estimated coefficients are statistically significant at the lowest commonly used significance level of 1 percent. Second, estimates of β, κ, θ, and λ have the sign expected from economic theory, while α and γ do not; in particular, it is puzzling that the slope of the IS function, α, is positive rather than negative; but, also, that the reaction of policy interest rates to the output gap, γ, is negative and statistically significant. Third, the magnitude of the estimate of λ also raises concerns: although it is compatible with the Taylor principle, it seems excessively high when compared to other studies for the euro area (Blattner & Margaritov, 2010).

The problems with the estimates of α, γ and λ raise doubts on the validity of our estimates. Despite the use of shadow interest rates – to capture the actual degree of accommodative monetary policy under the current scenario of ZLB and unconventional policy – we conjecture that the GFC and its severe impact on the euro area economy may have caused a structural break throughout the sample period 1999Q1-2019Q4.

---

[54] To obtain further information on FIML, see, for instance, Balestra and Varadharajan-Krishnakumar (1987), Fomby, Hill, and Johnson (1984), and Prucha (1985). One potential drawback of FIML is that the whole estimates are vulnerable to misspecifications in any of the system's equation. Such problem may be considered limited in the case of this dissertation as the 3-equation New Keynesian model that we used is standard in the literature.

[55] See Annexes.

To investigate such possibility, we conducted some structural stability tests. Notably, the Quandt-Andrews breakpoint test applied to the forward-looking IS curve – estimated individually over the same sample period by Ordinary Least Squares (OLS) – indicates a breakpoint in the fourth quarter of 2009. Such result suggests that the positive relationship between the output gap and the difference between ex-ante real interest rates and their long-term level may be the consequence of structural break induced by the liquidity trap that emerged after the GFC when official nominal interest rates reached their lower bound. As already stressed in the literature review, notwithstanding an unprecedent monetary easing, the output gap may not have resumed a sustainable recovery path yet, and hence the positive estimate of α. Additionally, the unexpectedly high estimate of λ may result from the unusual accommodative policy response, and the negative estimate of γ may reflect the fact that, unlike the Federal Reserve that aims at not only promoting price stability but also full employment, the ECB focuses more strongly on price stability.

However, these explanations should be read carefully, as they are mere hypotheses to explain the differences between our estimates and the expected values for those parameters. It is not the purpose of this dissertation to justify those differences, which would require further and more technical research. Rather, the purpose of this section is to obtain the coefficient estimates that are to be used throughout the simulation carried out in the following section.

To avoid the structural break arguably created by the GFC and the impact of the ensuing unconventional policy measures, the system composed of (3.1), (3.2), and (3.3) will be then reestimated for the period between the first quarter of 1999 and the second quarter of 2009. This period has been meticulously chosen to be the largest possible for which the ZLB has not been binding. In fact, the cut of the MRO rate to the then record low of 1 percent in May 2009 may have triggered the fear that the ZLB was likely to become an imminently serious constraint to the traditional conduct of monetary policy. The second quarter of 2009 therefore works well as a relevant breakpoint to study whether the adoption of an alternative policy framework thereafter would prevent the euro area from encountering the ZLB or at least reduce its duration.

The right panel of Table 3 shows the coefficient estimates and the corresponding p-values for the 1999Q1-2009Q2 sample period[56]. A number of interesting conclusions stand out from the estimation. First, apart from λ and γ, all the estimated parameters are significantly different from zero at the significance level of 1 percent. While λ is statistically significant at the next commonly used significance level of 5 percent, γ is not, even at the level of 10 percent. Second, we now obtain a negative estimate for α that is in accordance with economic theory. In this regard, the model as described estimates a 0.29 percentage points decrease of the output gap when the ex-ante real interest rate is 1 percentage point above its long-term value, everything else unchanged. Third, the estimate for λ remains compatible with the Taylor principle and is now closer to other estimates in the literature, as summarised by Blattner and Margaritov (2010). This estimate then denotes, all else being equal, that when inflation rates are 1 percentage point above the target, short-term nominal interest rates are expected to increase by 1.55 percentage points so that real rates may also increase, and monetary policy is stabilising.

After presenting the parameter estimates for 1999Q1-2009Q2, we now proceed to simulate the adoption of price-level targeting over the 2009Q3-2019Q4 period. The simulation results in terms of inflation expectations, inflation rates, output gap, and short-term nominal interest rates will be described throughout the following section, and compared to the observed values for those variables.

3.3 Simulation of the Model Assuming Price-Level Targeting

As stressed above, the goal of the empirical research in this dissertation is to investigate whether the timely adoption of an alternative policy framework would have prevented the euro area from encountering the ZLB or at least would have reduced the duration and the severity that this constraint has embodied since the GFC. To do so, this section will try to simulate the 2009Q3-2019Q4 path of inflation expectations, inflation rates, output gap, and short-term nominal interest rates, if the ECB had decided to change from the current inflation targeting regime to a price-level targeting. This dissertation assumes that this

[56] The estimation method has remained unchanged and, even though unconventional policy measures had not been implemented until the second quarter of 2009, this estimation has also used shadow interest rates because they had not been considerably different from EONIA during this sample period – as expected.

adjustment will take place during the transition from the second quarter to the third quarter of 2009, which is motivated by that fact that the MRO rate had reached the then record low in May 2009 and fears of the imminence of the ZLB could have already emerged. All in all, the purpose of this section is to embrace a counterfactual analysis by comparing the simulated evolution of those variables to their observed values.

Having this in mind, this section will first present the methodology used to simulate the adoption of price-level targeting in the euro area. To clarify it, a numerical example will then be introduced. Perceived limitations of this methodology will also be addressed. Finally, this section will provide the simulation results, and compare them with the observed path for the variables under investigation.

3.3.1 Methodology

Two identities are introduced in the original model constituted of stochastic equations (3.1), (3.2), and (3.3) so as to simulate price-level targeting. This approach is expected to mimic the approach of Mertens and Williams (2019), albeit in a simpler form merely aiming at capturing the essence of the functioning of that alternative policy regime.

The first identity included in the original model is an equation for determining the current price level. The natural logarithm of the current price level, p_t, is then equal to the natural logarithm of the previous price level plus the current inflation rate as follows:[57]

$$(3.8)\ p_t = p_{t-1} + \pi_t/100.$$

[57] Due to the fact that actual inflation rates used within this model are calculated as the annual rate of change between a quarter and the same quarter in the previous year, one needs to bear in mind that price level each quarter is in practice computed by using the price level observed four quarters ago and not the price level in the previous quarter. To give an example, the price level in the third quarter of 2009 will be calculated by using the observed price level in the same quarter of 2008 plus the annual inflation rate noticed in the third quarter of 2009. Since the time series for the price level will be simulated from 2009Q3 onwards, there is only the need to obtain the first four initial values, which will be retrieved from Eurostat with respect to the 2008Q3-2009Q2 period.

The second identity aims at describing the inflation expectations' formation process under this new policy framework, according to the following specification:[58]

$$(3.9)\ \mathbb{E}_t[\pi_{t+1}|p_t] = 100 * (p^*_{t+1} - p_t),$$

where $\mathbb{E}_t[\pi_{t+1}|p_t]$ is the expected future inflation assuming price-level targeting and p^*_{t+1} is the natural logarithm of the price level target for the next period. Inflation expectations would then become a function of both the price level target and the observed price level.

Equation (3.9) is of the utmost importance for the simulation held throughout this section, since it embodies the role of inflation expectations as automatic stabilisers. Recall how price-level targeting works: when the current price level is, for instance, below the contemporaneous price level target, meaning that the current inflation rate is below the inflation rate implicit in the target path for the price level,[59] then economic agents expect inflation for the next period to be higher than the implicit inflation target so as to allow the return of the price level to its target level. Assuming that economic agents believe that the ECB would be fully committed to pursuing a price level target previously announced, it is then legitimate to assume that one-year-ahead inflation expectations would be given by the difference between the one-year-ahead price level target and the current price level.

In order to better comprehend this methodology, a numerical example will be provided throughout next subsection.

---

[58] Again, as a consequence of using quarterly data, this identity should be understood in practice as the expected inflation rate in a given quarter to take place four quarters ahead. This means that the price level target is actually that defined four quarters ahead by the central bank. In so doing, data for the observed price level between 2008Q3 and 2009Q2 will also be used as the initial values for determining the target path for price level from 2009Q3 onwards. For instance, the perceived price level target in 2009Q3 will be assumed to be equal to the observed price level in 2008Q3 plus the implicit inflation rate in the target path for the price level. The price level target for 2010Q3 will in turn be based on the price level target for the 2009Q3 plus the implicit inflation target, and so on and so forth.

[59] The inflation rate implicit in the target path for the price level will be assumed throughout the simulation to be equal to the current inflation target of 2 percent.

3.3.2 A Numerical Example

To give a numerical example, assume that an economy is at its steady state at t=0 where both the observed price level and the price level target are equal to 100. Assuming an implicit inflation target of 2 percent, then the central bank's goal for the next period (t=1) is to achieve a price level of around 102. Now suppose that a negative shock occurs at t=1 and the price level is 101 in this period, which implies an observed inflation rate of 1 percent that is below the 2 percent implicit inflation target. Therefore, assuming that the central bank is fully committed to making up for deviations of price level from its target, and that economic agents know the observed price level at t=1 (101) and the price level target at t=2 (around 104), then inflation expectations at t=1 for inflation rates at t=2 are roughly equal to 3 percent. This mechanism of expecting inflation rates above or below the inflation rate implicit in the price level target continues over time until inflation expectations stabilise around 2 percent.

In other words, this numerical example shows why Budianto, Nakata, and Schmidt (2020) have stated that price-level targeting might be understood as an equivalent framework to average inflation targeting when the averaging window is infinitely long. Indeed, future inflation expectations formulated in a given period under this approach could alternatively be seen as the inflation rate that would be needed in the following period for the average inflation rate until then – that is, the moving average inflation rate – to be equal to 2 percent.

Before discussing the simulation results themselves, the following subsection will address the potential limitations of the methodology employed.

3.3.3 Potential Limitations of the Methodology

Our methodology to simulate price-level targeting has two main potential limitations.

First, our procedure does not take into account the monetary policy response, namely not adjusting short-term nominal interest rates to the price level deviation; with this respect, it differs from the procedure used for instance by Bernanke et al. (2019), where a deviation of the observed price level from its target is added to the standard Taylor (1993) rule, and by other authors such as Giannoni (2014), in which the deviation of the inflation rate from its target is replaced by the price level deviation relatively to the predefined target level. This may encompass a challenge for the simulation here undertaken, as the specification of the monetary policy rule (3.3) is kept unchanged whether the ECB embraces inflation targeting

or price-level targeting. Despite that limitation, there are several motivations for using the aforementioned approach. First of all, as noted above, the inflation expectations' formation process given by equation (3.9) would already capture most of the essence of price-level targeting, especially the role of inflation expectations as automatic stabilisers. Furthermore, the explicit consideration of a price level deviation within the monetary policy rule would raise the problem of how to calibrate its coefficient, because that parameter cannot be estimated since price-level targeting has never been implemented in the euro area. Finally, the introduction of the price level deviation in the monetary policy rule could alter the other parameter estimates as well.

A second limitation of our simulation procedure is the assumption that economic agents would immediately understand the functioning of price-level targeting and would instantly believe in the full commitment of monetary policymakers to reversing past price level deviations. Indeed, it is not obvious that economic agents do not need an experimental period of time to gradually learn how this alternative policy framework works in practice. Also, for the commitment of the ECB to pursuing price-level targeting to be credible, it may be required that economic agents first observe the conduct of monetary policy and then evaluate whether it is compatible with the announced price level target (Bodenstein, Hebden, & Winkler, 2019; Svensson, 2020).

3.3.4 Simulation Results

We now describe the results of our simulation of a price-level targeting monetary regime, conducted along the lines explained above and using the EViews simulation tool.[60] In so doing, the simulated values for inflation expectations, inflation rates, output gap, and short-term nominal interest rates will be compared with their actual values between the third quarter of 2009 and the fourth quarter of 2019. Results are summarised in Figure 20.[61]

Regarding the behaviour of the first variable of interest, the first chart in Figure 20 shows that the implementation of price-level targeting would generate inflation expectations systematically higher than those actually formulated under inflation targeting, and keep the

[60] The simulation type will be configured to stochastic and the simulation itself will be assumed to be dynamic. The solution sample was set to the period between 2009Q3 and 2019Q4.

[61] The observed paths of those variables before 2009Q3 are also displayed in Figure 20. See Annexes.

economy safely away from any deflationary risks. In short, the alternative policy framework aiming at a predefined price level target avoids the fall in expectations of inflation seen in the data. In particular, the first chart of Figure 20 tells the following story. After the GFC, expected inflation rates would have suddenly increase but not towards levels as high as in the subsequent quarters. Indeed, throughout the period that followed the euro area sovereign debt crisis, inflation expectations would have reached high values – greater than 2 percent – consistent with a simulated price level below the price level target. In the most recent quarters, inflation expectations would have decreased towards 2 percent, the implicit inflation target.

Moving now to the simulated path for inflation rates, the second chart in the figure allows for concluding that, after an initial upsurge towards 2 percent, they would clearly be more stable around that value had the ECB adopted price-level targeting. This may contrast with the initial perception that this policy framework would generate greater volatility of inflation, since it allows inflation rates to be higher or lower than the implicit inflation target as long as the price level differs from its target. We argue that the result regarding simulated inflation rates may be the consequence of incorporating forward-looking inflation expectations – which act as automatic stabilisers in the model (Svensson, 2020).

As may be seen in the third chart in Figure 20, the simulated path for the output gap is quite similar to the observed one, although the former is slightly higher than the latter. Both actual and simulated gaps record an initial shy recovery after the GFC towards still negative values. Then, with the sovereign debt crisis, the simulated output gap would have fallen likewise the actual gap, and then would have followed the upward trend seen in the actual output gap during the most recent years.

Finally, with regard to the simulated path of short-term nominal interest rates, the last chart in Figure 20 shows the breakthrough conclusion that the timely implementation of price-level targeting in the third quarter of 2009 would have prevented the euro area from reaching the ZLB. Indeed, simulated short-term nominal interest rates would have rapidly increased immediately after the GFC and the start of our simulation exercise, and would have remained at levels considerably above zero, hence allowing sufficient cushion for lowering interest rates in the face of another severe shock to the euro area.

Given the above described results for the simulations of the output gap, inflation and inflation expectations, it seems fair to conclude from our exercise that, as expected from the

theory and the *rationale* for price-level targeting, inflation expectations pay a crucial role in the success of this monetary regime to prevent the ZLB.

4 Concluding Remarks

Given the observation that the ZLB has become a serious constraint for the traditional conduct of monetary policy, especially since the GFC, this dissertation has tried to figure out whether this phenomenon has been essentially a consequence of the fact that inflation targeting has become a victim of its own success, and thus a matter of monetary policy framework, or whether it has been the result of some structural change in the fundamentals that would occur regardless of the policy regime under consideration.

To address the first thesis, this dissertation has made a reflection upon the success of inflation targeting in lowering high and volatile inflation rates of the 1970s and early 1980s. However, by promoting a low inflation environment, central banks are then assuming a reduction in its margin to lower official nominal interest rates. Indeed, the lower the inflation, the lower the margin to reduce nominal interest rates to attain a given real interest rate. Having this is mind, one can easily understand that the monetary policy response becomes more constrained when shocks that affect the economy are particularly severe.

This thesis may have then called into question the fact that inflation targeting may have reached its expiration date because it does not seem a robust regime to address deep economic recessions. In other words, remembering the good-luck hypothesis for the emergence of the GM, we now can address this problem in a slightly different way. In fact, assuming that the GFC was the first big challenge to inflation targeting, we could be tempted to conclude that the GM was mainly due to the absence of really severe shocks – hence the importance of the good-luck hypothesis. Overall, the severity of the GFC may have exposed that this policy framework could not be well suited to address deep economic recessions.

In this regard, even if the second thesis mentioned above – a structural change in the fundamentals – may have played the main role in generating a permanent ZLB, it will be nevertheless of the utmost importance to discuss some alternative proposals to inflation targeting that may prove better suited to address the permanence of the ZLB.

Having this in mind, this dissertation has made a contrafactual analysis to assess whether the adoption of price-level targeting in the euro area between 2009Q3 and 2019Q4 would have prevent this monetary union from bearing the costs of the ZLB.

The simulation results were relatively favourable for the implementation of price-level targeting since it would have protected the euro area against the severity of the ZLB. This

result then heavily depends on the inflation expectations' formation process under price-level targeting.

Nevertheless, this result should be read carefully because of the following statements. First, as mentioned above, the simulation methodology may not be exempted from some limitations. Second, there is evidence of a significant downward trend in natural real interest rates. Regarding the second statement, a secular decline in natural real interest rates may be then the major contributor to the permanence of the ZLB, rather than the first thesis mentioned above,

To sum up, despite the simulation employed shows the contrary, that is, the adoption of price-level targeting would have prevented the euro area from bearing the costs of the ZLB, the truth is that the permanence of the ZLB in the euro area may be instead a consequence of the secular decline in natural real interest rates and thus regardless of the monetary policy framework. Hence, the permanence of the ZLB may not be a matter of monetary policy framework, but rather a consequence of a relevant structural change in the fundamentals. As it is easily understood, a downward trend in natural real interest rates means that an even lower real interest rate is required so that monetary policy is expansionary. And given that nominal interest rates are not able to be reduced further below zero or a small negative value, the ZLB is likely to become a more frequent binding constraint henceforth.

5 Bibliographic References

Ahmed, S., Levin, A., & Wilson, B. (2004). Recent U.S. Macroeconomic Stability: Good Policies, Good Practices, or Good Luck? *The Review of Economics and Statistics, 86*(3), 824-832. doi:10.1162/0034653041811662

Akerlof, G. A., Dickens, W. T., & Perry, G. L. (1996). The Macroeconomics of Low Inflation. *Brookings Papers on Economic Activity, 1996*(1), 1-76. doi:10.2307/2534646

Balestra, P., & Varadharajan-Krishnakumar, J. (1987). Full Information Estimations of a System of Simultaneous Equations with Error Component Structure. *Econometric Theory, 3*(2), 223-246. Retrieved from http://www.jstor.org/stable/3532463

Ball, L. M. (2014). *The Case for a Long-Run Inflation Target of Four Percent*. IMF Working Paper 14/92. International Monetary Fund. Retrieved from https://www.imf.org/external/pubs/ft/wp/2014/wp1492.pdf

Bauer, M. D., & Rudebusch, G. D. (2014). The Signaling Channel for Federal Reserve Bond Purchases. *International Journal of Central Banking, 10*(3), 233-289. Retrieved from https://www.ijcb.org/journal/ijcb14q3a7.pdf

Beckworth, D., & Hendrickson, J. R. (2020). Nominal GDP Targeting and the Taylor Rule on an Even Playing Field. *Journal of Money, Credit and Banking, 52*(1), 269-286. doi:10.1111/jmcb.12602

Belz, S., & Wessel, D. (2019). *What is Yield Curve Control?* The Hutchins Center Explains. Brookings Institution. Retrieved from https://www.brookings.edu/blog/up-front/2019/08/14/what-is-yield-curve-control/

Bernanke, B. S. (2004). *The Great Moderation*. Remarks by Governor Ben S. Bernanke at the meetings of the Eastern Economic Association. The Federal Reserve Board. Washington, DC, February 20, 2004. Retrieved from https://www.federalreserve.gov/boarddocs/speeches/2004/20040220/

Bernanke, B. S. (2005). *The Global Saving Glut and the U.S. Current Account Deficit*. Remarks by Governor Ben S. Bernanke at the Homer Jones Lecture. The Federal Reserve Board. St. Louis, Missouri, April 14, 2005. Retrieved from https://www.federalreserve.gov/boarddocs/speeches/2005/20050414/default.htm

Bernanke, B. S. (2007). *Inflation Expectations and Inflation Forecasting*. Speech by Chairman Ben S. Bernanke at the Monetary Economics Workshop of the National Bureau of Economic Research. Board of Governors of the Federal Reserve System. Summer Institute, Cambridge, Massachusetts, July 10, 2007. Retrieved from https://www.federalreserve.gov/newsevents/speech/bernanke20070710a.htm

Bernanke, B. S. (2019). Monetary Policy in a New Era. In O. Blanchard & L. H. Summers (Eds.), *Evolution or Revolution?: Rethinking Macroeconomic Policy after the Great Recession* (pp. 3-48). Cambridge, MA: MIT Press.

Bernanke, B. S., Kiley, M. T., & Roberts, J. M. (2019). Monetary Policy Strategies for a Low-Rate Environment. *Aea Papers and Proceedings, 109*, 421-426. doi:10.1257/pandp.20191082

Bernanke, B. S., & Mishkin, F. S. (1997). Inflation Targeting: A New Framework for Monetary Policy? *Journal of Economic Perspectives, 11*(2), 97-116. doi:10.1257/jep.11.2.97

Beyer, R. C. M., & Wieland, V. (2019). Instability, Imprecision and Inconsistent Use of Equilibrium Real Interest Rate Estimates. *Journal of International Money and Finance, 94*, 1-14. doi:10.1016/j.jimonfin.2019.01.005

Billi, R. M., & Kahn, G. A. (2008). What is the Optimal Inflation Rate? *Federal Reserve Bank of Kansas City Economic Review, 93*(2), 5-28. Retrieved from https://www.kansascityfed.org/PUBLICAT/ECONREV/PDF/2q08billi_kahn.pdf

Blanchard, O., Dell'Ariccia, G., & Mauro, P. (2010). Rethinking Macroeconomic Policy. *Journal of Money, Credit and Banking, 42*(S1), 199-215. doi:10.1111/j.1538-4616.2010.00334.x

Blanchard, O., & Simon, J. (2001). The Long and Large Decline in U.S. Output Volatility. *Brookings Papers on Economic Activity, 2001*(1), 135-164. Retrieved from www.jstor.org/stable/1209161

Blattner, T. S., & Margaritov, E. (2010). *Towards a Robust Monetary Policy Rule for the Euro Area*. ECB Working Paper 1210. European Central Bank. Retrieved from https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1210.pdf

Bodenstein, M., Hebden, J., & Winkler, F. (2019). *Learning and Misperception: Implications for Price-Level Targeting*. FEDS Working Paper 2019-078. Board of Governors of the Federal Reserve System. Retrieved from https://www.federalreserve.gov/econres/feds/files/2019078pap.pdf

Bonis, B., Ihrig, J., & Wei, M. (2017). *The Effect of the Federal Reserve's Securities Holdings on Longer-term Interest Rates*. FEDS Notes. Board of Governors of the Federal Reserve System. Washington, DC, April 20, 2017. Retrieved from https://www.federalreserve.gov/econres/notes/feds-notes/effect-of-the-federal-reserves-securities-holdings-on-longer-term-interest-rates-20170420.htm

Bordo, M. D. (2008). *An Historical Perspective on the Crisis of 2007-2008*. NBER Working Paper 14569. National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w14569.pdf

Borio, C., & Zabai, A. (2016). *Unconventional Monetary Policies: A Re-appraisal*. BIS Working Paper 570. Bank for International Settlements. Retrieved from https://www.bis.org/publ/work570.pdf

Brainard, L. (2019). Rethinking Monetary Policy in a New Normal. In O. Blanchard & L. H. Summers (Eds.), *Evolution or Revolution?: Rethinking Macroeconomic Policy after the Great Recession* (pp. 49-59). Cambridge, MA: MIT Press.

Budianto, F., Nakata, T., & Schmidt, S. (2020). *Average Inflation Targeting and the Interest Rate Lower Bound*. BIS Working Paper 852. Bank for International Settlements. Retrieved from https://www.bis.org/publ/work852.pdf

Burke, C., Hilton, S., Judson, R., Lewis, K., & Skeie, D. (2010). *Reducing the IOER Rate: An Analysis of Options*. Memorandum to the Federal Open Market Committee. Washington, DC, August 5, 2010. Retrieved from https://www.federalreserve.gov/monetarypolicy/files/FOMC20100805memo05.pdf

Caballero, R. J., Farhi, E., & Gourinchas, P. O. (2017). The Safe Assets Shortage Conundrum. *Journal of Economic Perspectives, 31*(3), 29-46. doi:10.1257/jep.31.3.29

Carlstrom, C., & Pescatori, A. (2009). *Conducting Monetary Policy When Interest Rates Are Near Zero*. Economic Commentary. Federal Reserve Bank of Cleveland. Retrieved from https://www.clevelandfed.org/en/newsroom-and-events/publications/economic-

commentary/economic-commentary-archives/2009-economic-commentaries/ec-20091009-conducting-monetary-policy-when-interest-rates-are-near-zero.aspx

Cecchetti, S. G., Flores-Lagunes, A., & Krause, S. (2006). *Assessing the Sources of Changes in the Volatility of Real Growth*. NBER Working Paper 11946. National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w11946.pdf

Claessens, S., Dell'Ariccia, G., Igan, D., & Laeven, L. (2010). *Lessons and Policy Implications from the Global Financial Crisis*. IMF Working Paper 10/44. International Monetary Fund. Retrieved from http://www.imf.org/external/pubs/ft/wp/2010/wp1044.pdf

Clarida, R., Galí, J., & Gertler, M. (1999). The Science of Monetary Policy: A New Keynesian Perspective. *Journal of Economic Literature, 37*(4), 1661-1707. doi:10.1257/jel.37.4.1661

Clarida, R., Galí, J., & Gertler, M. (2000). Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. *The Quarterly Journal of Economics, 115*(1), 147-180. doi:10.1162/003355300554692

Cole, S. J. (2018). The Effectiveness of Central Bank Forward Guidance under Inflation and Price-Level Targeting. *Journal of Macroeconomics, 55*, 146-161. doi:10.1016/j.jmacro.2017.10.008

Constâncio, V. (2016). *The Challenge of Low Real Interest Rates for Monetary Policy*. Lecture by Vítor Constâncio, Vice-President of the ECB, Macroeconomics Symposium at Utrecht School of Economics. European Central Bank. Utrecht, The Netherlands, June 15, 2016. Retrieved from https://www.ecb.europa.eu/press/key/date/2016/html/sp160615.en.html

Constâncio, V. (2017). *The Future of Monetary Policy Frameworks*. Lecture by Vítor Constâncio, Vice-President of the ECB, at Instituto Superior de Economia e Gestão. European Central Bank. Lisbon, Portugal, May 25, 2017. Retrieved from https://www.ecb.europa.eu/press/key/date/2017/html/ecb.sp170525.en.html

Cour-Thimann, P., & Winkler, B. (2012). The ECB's Non-standard Monetary Policy Measures: the Role of Institutional Factors and Financial Structure. *Oxford Review of Economic Policy, 28*(4), 765-803. doi:10.1093/oxrep/grs038

Draghi, M. (2019). Historical Lessons from the Euro Area Crisis for Monetary Policy. In O. Blanchard & L. H. Summers (Eds.), *Evolution or Revolution?: Rethinking Macroeconomic Policy after the Great Recession* (pp. 71-78). Cambridge, MA: MIT Press.

ECB. (2020a). Asset Purchase Programmes. Retrieved from https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html

ECB. (2020b). Key ECB Interest Rates. Retrieved from https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html

Eggertsson, G. B., & Woodford, M. (2003). The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity, 2003*(1), 139-211. Retrieved from www.jstor.org/stable/1209148

Evans, C. L. (2012). Monetary Policy in a Low-Inflation Environment: Developing a State-Contingent Price-Level Target. *Journal of Money Credit and Banking, 44*, 147-155. doi:10.1111/j.1538-4616.2011.00482.x

Fackler, J. S., & McMillin, W. D. (2019). *An Evaluation of Nominal GDP versus Price-Level Targeting*. Policy Brief. Mercatus Center, George Mason University. Retrieved from https://www.mercatus.org/system/files/fackler_and_mcmillin_-_policy_brief_-_an_evaluation_of_nominal_gdp_versus_price_level_targeting_-_v1.pdf

Fackler, J. S., & McMillin, W. D. (2020). Nominal GDP versus Price-Level Targeting: An Empirical Evaluation. *Journal of Economics and Business, 109*, 105890. doi:10.1016/j.jeconbus.2019.105890

Ferrero, G., Gross, M., & Neri, S. (2019). On Secular Stagnation and Low Interest Rates: Demography Matters. *International Finance, 22*(3), 262-278. doi:10.1111/infi.12342

Fomby, T. B., Hill, R. C., & Johnson, S. R. (1984). Full Information Estimation. In T. B. Fomby, R. C. Hill, & S. R. Johnson (Eds.), *Advanced Econometric Methods* (pp. 499-511). New York, NY: Springer

Garín, J., Lester, R., & Sims, E. (2016). On the Desirability of Nominal GDP Targeting. *Journal of Economic Dynamics and Control, 69*, 21-44. doi:10.1016/j.jedc.2016.05.004

Garnier, J., & Wilhelmsen, B.-R. (2009). The Natural Rate of Interest and the Output Gap in the Euro Area: A Joint Estimation. *Empirical Economics, 36*(2), 297-319. doi:10.1007/s00181-008-0196-z

Gaspar, V., Smets, F., & Vestin, D. (2010). Is the Time Ripe for Price-Level Path Stability? In P. Siklos, M. Bohl, & M. Wohar (Eds.), *Challenges in Central Banking: The Current Institutional Environment and Forces Affecting Monetary Policy* (pp. 21-51). Cambridge: Cambridge University Press.

Giannoni, M. P. (2014). Optimal Interest-Rate Rules and Inflation Stabilization versus Price-Level Stabilization. *Journal of Economic Dynamics and Control, 41*, 110-129. doi:10.1016/j.jedc.2014.01.013

Giannoni, M. P., & Woodford, M. (2003). *Optimal Inflation Targeting Rules*. NBER Working Paper 9939. National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w9939.pdf

Gillitzer, C., & Simon, J. (2015). Inflation Targeting: A Victim of Its Own Success. *International Journal of Central Banking, 11*(S1), 259-287. Retrieved from https://www.ijcb.org/journal/ijcb15q4a8.pdf

Gorodnichenko, Y., & Shapiro, M. D. (2007). Monetary Policy when Potential Output is Uncertain: Understanding the Growth Gamble of the 1990s. *Journal of Monetary Economics, 54*(4), 1132-1162. doi:10.1016/j.jmoneco.2006.03.004

Guthrie, G., & Wright, J. (2000). Open Mouth Operations. *Journal of Monetary Economics, 46*(2), 489-516. doi:10.1016/s0304-3932(00)00035-0

Holston, K., Laubach, T., & Williams, J. C. (2017). Measuring the Natural Rate of Interest: International Trends and Determinants. *Journal of International Economics, 108*, S59-S75. doi:10.1016/j.jinteco.2017.01.004

IMF. (2013). *Unconventional Monetary Policies - Recent Experience and Prospects*. International Monetary Fund. Retrieved from https://www.imf.org/external/np/pp/eng/2013/041813a.pdf

Issing, O. (1999). *The Monetary Policy of the ECB: Stability, Transparency, Accountability*. Speech by Professor Otmar Issing, Member of the Executive Board of the ECB, at the Royal Institute of International Affairs. European Central Bank. London, October 25,

1999. Retrieved from https://www.ecb.europa.eu/press/key/date/1999/html/sp991025_1.en.html

Kahn, G. A. (2009). Beyond Inflation Targeting: Should Central Banks Target the Price Level? *Federal Reserve Bank of Kansas City Economic Review, 94*(3), 35-64. Retrieved from https://www.kansascityfed.org/~/media/files/publicat/econrev/econrevarchive/2009/3q09kahn.pdf

Kiley, M. T. (2018). Quantitative Easing and the 'New Normal' in Monetary Policy. *The Manchester School, 86*(S1), 21-49. doi:10.1111/manc.12238

Krippner, L. (2013). Measuring the Stance of Monetary Policy in Zero Lower Bound Environments. *Economics Letters, 118*(1), 135-138. doi:10.1016/j.econlet.2012.10.011

Krugman, P. R. (1998). It's Baaack: Japan's Slump and the Return of the Liquidity Trap. *Brookings Papers on Economic Activity, 1998*(2), 137-205. doi:10.2307/2534694

Lane, P. R. (2012). The European Sovereign Debt Crisis. *Journal of Economic Perspectives, 26*(3), 49-68. doi:10.1257/jep.26.3.49

Laubach, T., & Williams, J. C. (2003). Measuring The Natural Rate of Interest. *The Review of Economics and Statistics, 85*(4), 1063-1070. doi:10.1162/003465303772815934

Laubach, T., & Williams, J. C. (2016). Measuring the Natural Rate of Interest Redux. *Business Economics, 51*, 57-67. doi:10.1057/be.2016.23

Leamer, E. E. (2015). Housing Really Is the Business Cycle: What Survives the Lessons of 2008-09? *Journal of Money, Credit and Banking, 47*(S1), 43-50. doi:10.1111/jmcb.12189

McCallum, B. T. (1987). The Case for Rules in the Conduct of Monetary Policy: A Concrete Example. *Weltwirtschaftliches Archiv, 123*(3), 415-429. Retrieved from https://www.jstor.org/stable/40439395

McCallum, B. T. (1988). Robustness Properties of a Rule for Monetary Policy. *Carnegie-Rochester Conference Series on Public Policy, 29*, 173-203. doi:10.1016/0167-2231(88)90011-5

McCallum, B. T. (1999). Issues in the Design of Monetary Policy Rules. In J. B. Taylor & M. Woodford (Eds.), *Handbook of Macroeconomics* (Vol. 1, pp. 1483-1530). Amsterdam: North-Holland.

McConnell, M. M., & Perez-Quiros, G. (2000). Output Fluctuations in the United States: What Has Changed since the Early 1980's? *American Economic Review, 90*(5), 1464-1476. doi:10.1257/aer.90.5.1464

Mertens, T. M., & Williams, J. C. (2019). Monetary Policy Frameworks and the Effective Lower Bound on Interest Rates. *Aea Papers and Proceedings, 109*, 427-432. doi:10.1257/pandp.20191083

Mester, L. J. (2018). *Monetary Policy Frameworks*. Panel Remarks for the National Association for Business Economics and American Economic Association Session, "Coordinating Conventional and Unconventional Monetary Policies for Macroeconomic Stability". Federal Reserve Bank of Cleveland. Allied Social Science Associations Annual Meeting, Philadelphia, PA, January 5, 2018. Retrieved from https://www.clevelandfed.org/en/newsroom-and-events/speeches/sp-20180105-monetary-policy-frameworks.aspx

Mishkin, F. S. (2001). *From Monetary Targeting to Inflation Targeting: Lessons from Industrialized Countries*. Policy Research Working Paper 2684. The World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/19531/multi0page.pdf?sequence=1&isAllowed=y

Mishkin, F. S. (2011). *Monetary Policy Strategy: Lessons from the Crisis*. NBER Working Paper 16755. National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w16755.pdf

Mishkin, F. S., & Posen, A. S. (1997). Inflation Targeting: Lessons from Four Countries. *Federal Reserve Bank of New York Economic Policy Review, 3*(3), 9-110. Retrieved from https://www.newyorkfed.org/medialibrary/media/research/epr/1997/EPRvol3no3.pdf

Mojon, B. (2007). *Monetary Policy, Output Composition and the Great Moderation*. Working Paper 2007-07. Federal Reserve Bank of Chicago. Retrieved from https://www.chicagofed.org/publications/working-papers/2007/wp-07

Pescatori, A. (2008). *The Great Moderation: Good Luck, Good Policy, or Less Oil Dependence?* Economic Commentary. Federal Reserve Bank of Cleveland. Retrieved from https://www.clevelandfed.org/en/newsroom-and-events/publications/economic-

commentary/economic-commentary-archives/2008-economic-commentaries/ec-20080301-the-great-moderation-good-luck-good-policy-or-less-oil-dependence.aspx

Prucha, I. R. (1985). Maximum Likelihood and Instrumental Variable Estimation in Simultaneous Equation Systems with Error Components. *International Economic Review, 26*(2), 491-506. doi:10.2307/2526597

Stock, J. H., & Watson, M. W. (2003). *Has the Business Cycle Changed? Evidence and Explanations.* Prepared for the Federal Reserve Bank of Kansas City symposium "Monetary Policy and Uncertainty: Adapting to a Changing Economy". Jackson Hole, Wyoming, August 28 - 30, 2003. Retrieved from https://www.kansascityfed.org/publicat/sympos/2003/pdf/Stockwatson2003.pdf

Summers, L. H. (2014). U.S. Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bound. *Business Economics, 49*(2), 65-73. doi:10.1057/be.2014.13

Summers, P. M. (2005). What Caused the Great Moderation? Some Cross-Country Evidence. *Federal Reserve Bank of Kansas City Economic Review, 90*(3), 5-32. Retrieved from https://www.kansascityfed.org/publicat/econrev/pdf/3q05summ.pdf

Svensson, L. E. O. (1997). Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets. *European Economic Review, 41*(6), 1111-1146. doi:10.1016/s0014-2921(96)00055-4

Svensson, L. E. O. (2009). *Flexible Inflation Targeting – Lessons from the Financial Crisis*. Speech by Mr. Lars E. O. Svensson, Deputy Governor of the Sveriges Riksbank, at the workshop "Towards a New Framework for Monetary Policy? Lessons from the Crisis", organized by the Netherlands Bank. Amsterdam, September 21, 2009. Retrieved from https://www.bis.org/review/r090923d.pdf

Svensson, L. E. O. (2020). Monetary Policy Strategies for the Federal Reserve. *International Journal of Central Banking, 16*(1), 133-193. Retrieved from https://www.ijcb.org/journal/ijcb2002_3.pdf

Taylor, J. B. (1993). Discretion versus Policy Rules in Practice. *Carnegie-Rochester Conference Series on Public Policy, 39*, 195-214. doi:10.1016/0167-2231(93)90009-L

Walsh, C. E. (2009). Inflation Targeting: What Have We Learned? *International Finance, 12*(2), 195-233. doi:10.1111/j.1468-2362.2009.01236.x

Walsh, C. E. (2010). Central Bank Independence. In S. N. Durlauf & L. E. Blume (Eds.), *Monetary Economics* (pp. 21-26). London: Palgrave Macmillan.

Werning, I. (2011). *Managing a Liquidity Trap: Monetary and Fiscal Policy*. NBER Working Paper 17344. National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w17344.pdf

Williams, J. C. (2017). Preparing for the Next Storm: Reassessing Frameworks and Strategies in a Low R-star World. *FRBSF Economic Letter, 2017*(13), 1-8. Retrieved from https://www.frbsf.org/economic-research/files/el2017-13.pdf

Williamson, S. D. (2019). Low Real Interest Rates and the Zero Lower Bound. *Review of Economic Dynamics, 31*, 36-62. doi:10.1016/j.red.2018.12.003

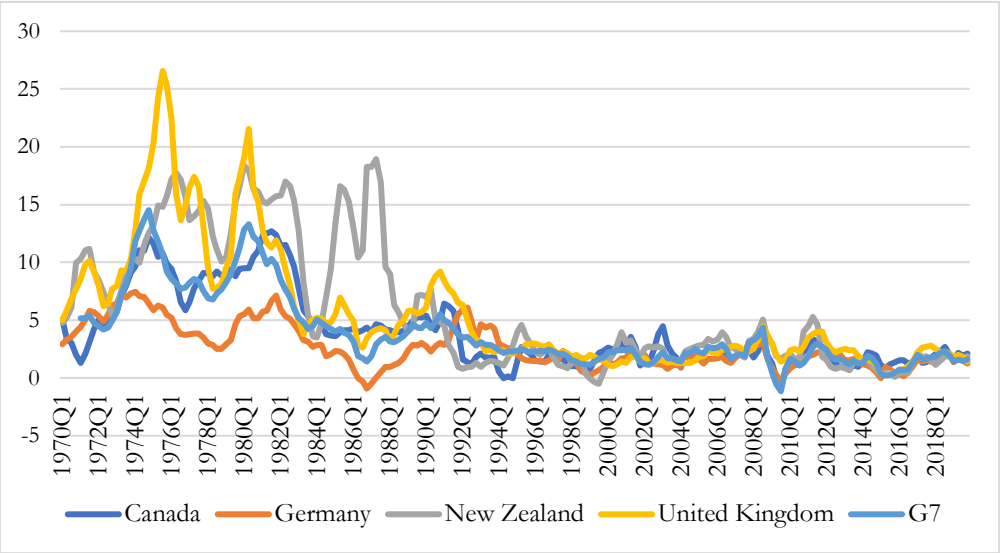
Woodford, M. (2009). Heeding Daedalus: Optimal Inflation and the Zero Lower Bound. Comment and Discussion. *Brookings Papers on Economic Activity, 2009*, 38-49. doi:http://www.brookings.edu/about/projects/bpea/past-editions

Wu, J. C., & Xia, F. D. (2016). Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound. *Journal of Money, Credit and Banking, 48*(2-3), 253-291. doi:10.1111/jmcb.12300

6 Annexes

6.1 Figures

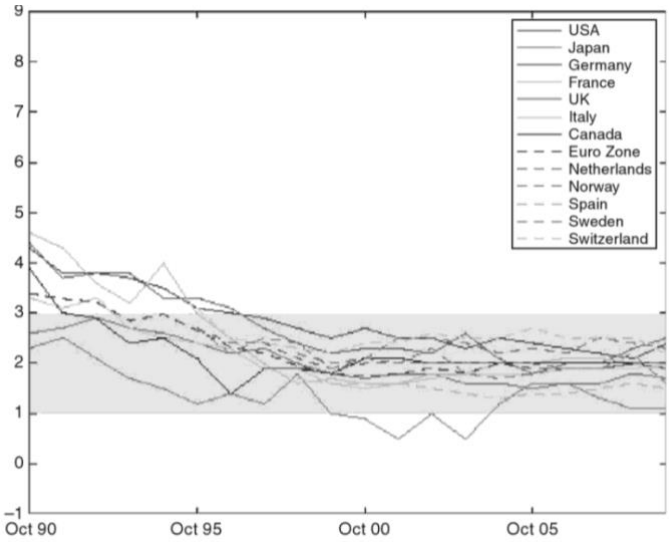
Figure 1. Inflation rates from 1970Q1 to 2019Q4 in selected OECD countries.



Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database; Last accessed on September 26, 2020; Series name: Inflation (CPI); Available at https://data.oecd.org/price/inflation-cpi.htm.

Notes: For G7 countries, data on inflation rates is only available from 1971Q1 to 2019Q4; Total inflation; Annual growth rate (%).

Figure 2. Long-term inflation expectations (6-to-10-years forecast) in selected OECD countries.



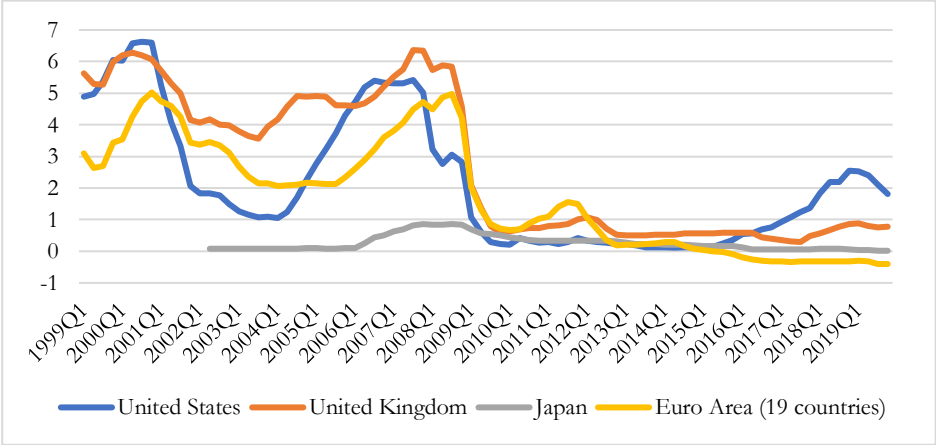
Source: Consensus Economics.

Figure 3. Interest rates on the main refinancing operations (MRO) since 1999.

Source: ECB (2020b).

Notes: From 28 June 2000 to 15 October 2008, the main refinancing operations of the Eurosystem were conducted at a variable rate instead of a fixed rate, hence the plotted values during this period refer to the minimum bid rate. Throughout the other periods, they were (and currently are) carried out at a fixed rate.

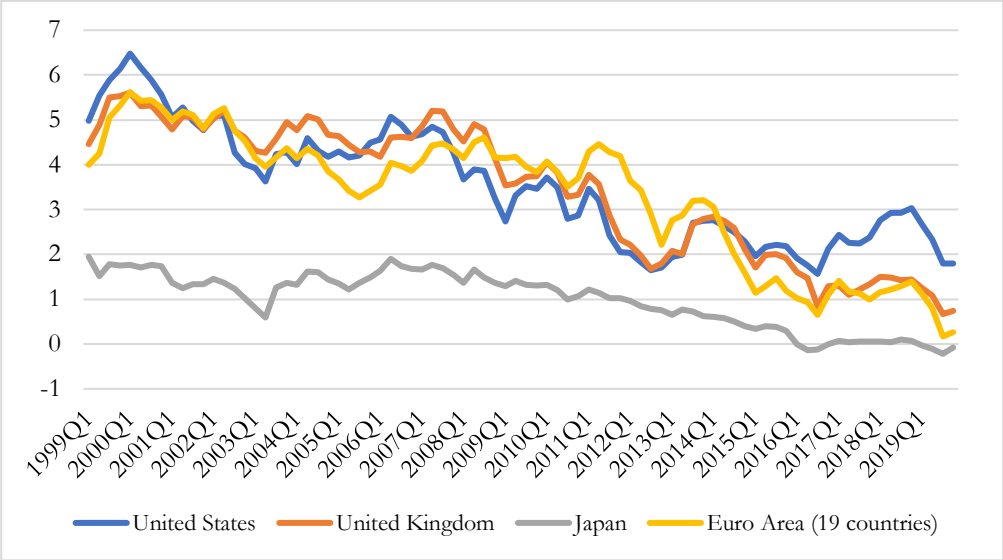
Figure 4. Short-term nominal interest rates from 1999Q1 to 2019Q4 in the most advanced economies.



Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database; Last accessed on September 26, 2020; Series name: Short-term interest rates; Available at https://data.oecd.org/interest/short-term-interest-rates.htm.

Notes: For Japan, data on short-term nominal interest rates is only available from 2002Q2 to 2019Q4; % per annum; By definition, "short-term interest rates are the rates at which short-term borrowings are effected between financial institutions or the rate at which short-term government paper is issued or traded in the market. Short-term interest rates are generally averages of daily rates, measured as a percentage. Short-term interest rates are based on three-month money market rates where available. Typical standardised names are 'money market rat' and 'treasury bill rate'."

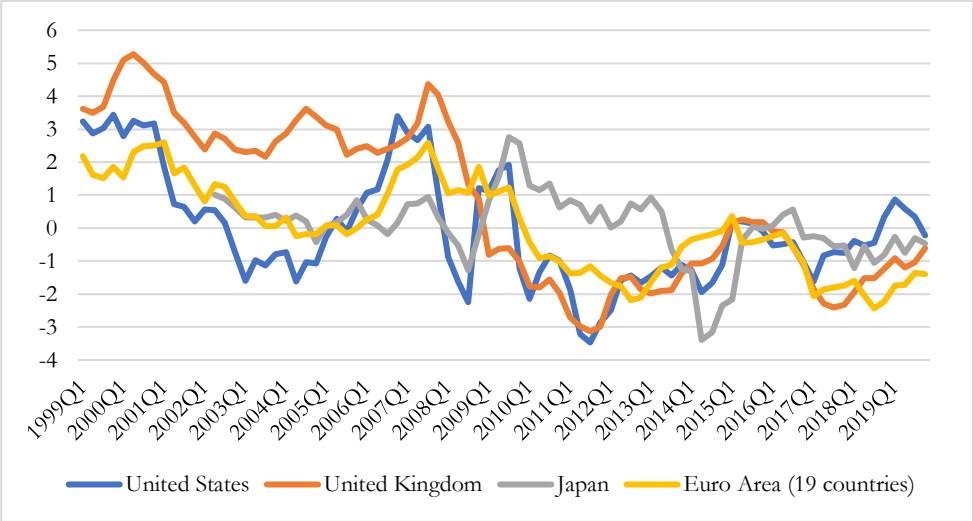
Figure 5. Long-term nominal interest rates from 1999Q1 to 2019Q4 in the most advanced economies.



Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database; Last accessed on September 26, 2020; Series name: Long-term interest rates; Available at https://data.oecd.org/interest/long-term-interest-rates.htm.

Notes: % per annum; By definition, "long-term interest rates refer to government bonds maturing in ten years. Rates are mainly determined by the price charged by the lender, the risk from the borrower and the fall in the capital value. Long-term interest rates are generally averages of daily rates, measured as a percentage. These interest rates are implied by the prices at which the government bonds are traded on financial markets, not the interest rates at which the loans were issued. In all cases, they refer to bonds whose capital repayment is guaranteed by governments. Long-term interest rates are one of the determinants of business investment. Low long-term interest rates encourage investment in new equipment and high interest rates discourage it. Investment is, in turn, a major source of economic growth".

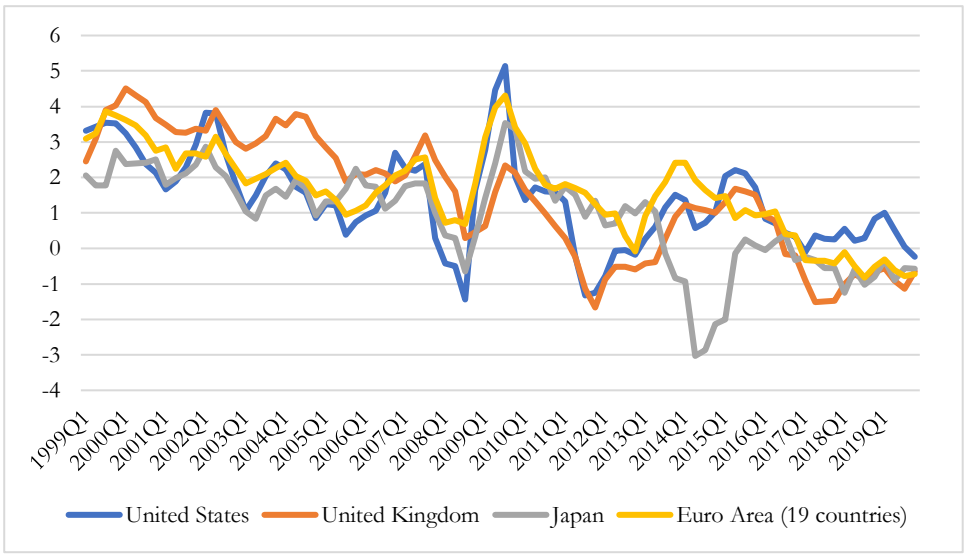
Figure 6. Ex-post short-term real interest rates from 1999Q1 to 2019Q4 in the most advanced economies.



Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database.

Notes: Author's calculation based on data plotted in Figure 4 and 9; Ex-post short-term real interest rates were assumed to be equal to the difference between short-term nominal interest rates and inflation rates.

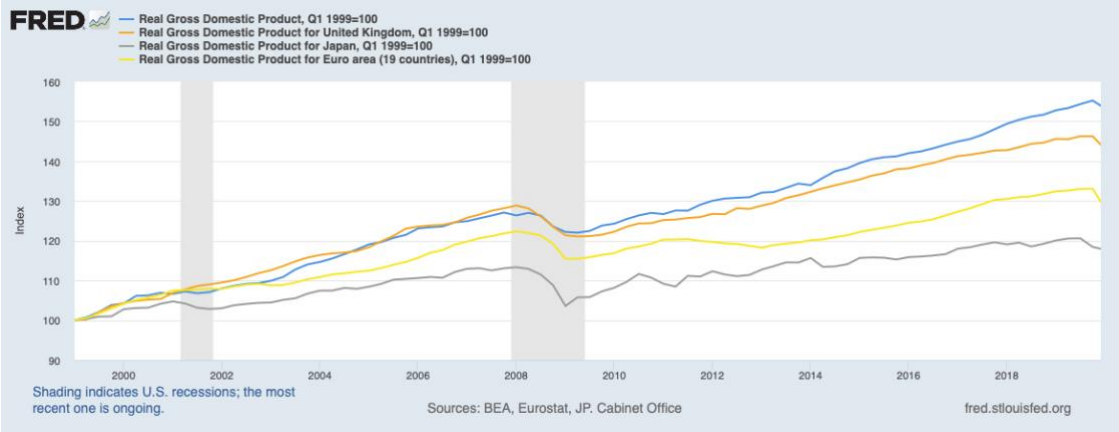
Figure 7. Ex-post long-term real interest rates from 1999Q1 to 2019Q4 in the most advanced economies.



Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database.

Notes: Author's calculation based on data plotted in Figure 5 and 9; Ex-post long-term real interest rates were assumed to be equal to the difference between long-term nominal interest rates and inflation rates.

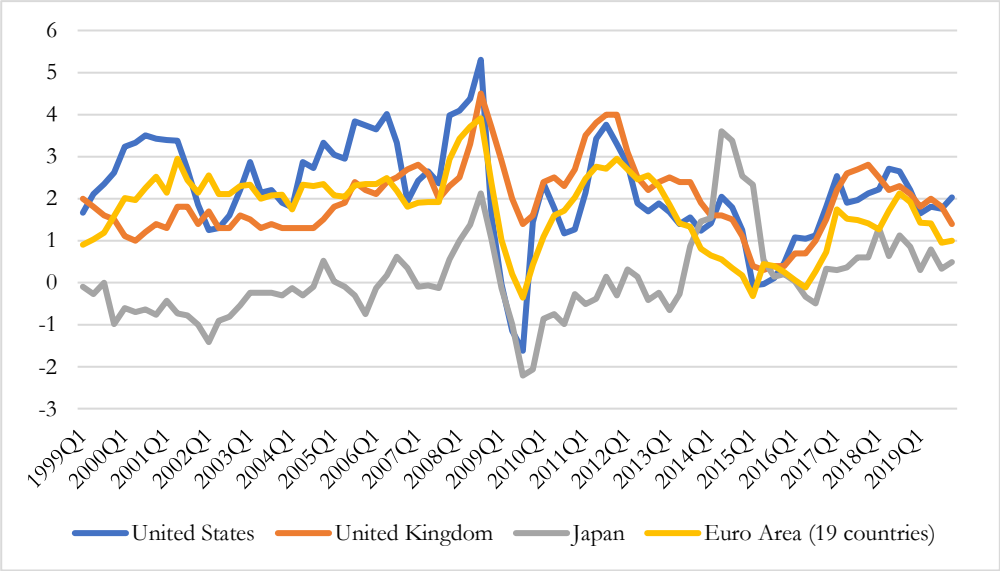
Figure 8. Real gross domestic product (GDP) from 1999Q1 to 2019Q4 in the most advanced economies.



Source: FRED Economic Data – Federal Reserve Bank of St. Louis; Last accessed on September 26, 2020; Series name: Real gross domestic product; Available at https://fred.stlouisfed.org/series/GDPC1#0.

Notes: For comparison purposes, data is plotted as an index that equals 100 in 1999Q1 for all the economies; Left shading area refers to the recession caused by the collapse of the dot-com bubble and later by the attacks of September 11th, and the second one represents the GFC.

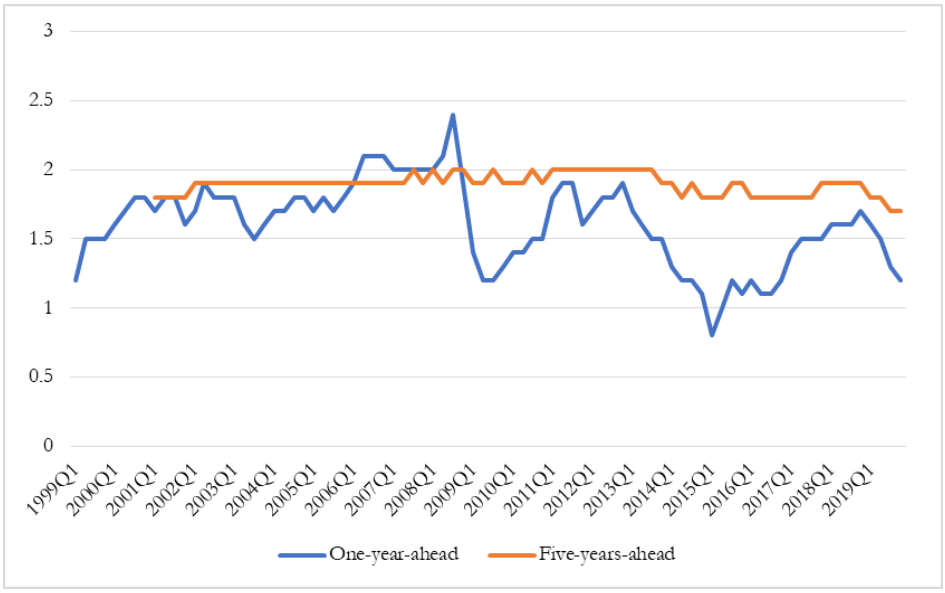
Figure 9. Inflation rates from 1999Q1 to 2019Q4 in the most advanced economies.



Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database; Last accessed on September 26, 2020; Series name: Inflation (CPI); Available at https://data.oecd.org/price/inflation-cpi.htm.

Notes: Total inflation; Annual growth rate (%).

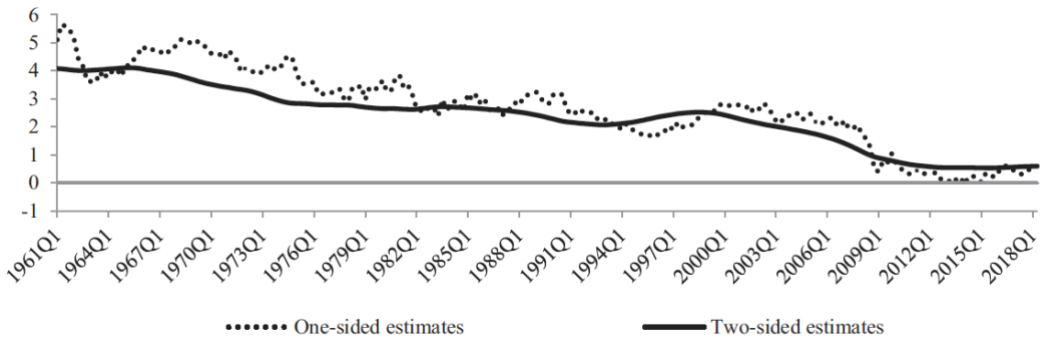
Figure 10. One-year-ahead and five-years-ahead inflation expectations from 1999Q1 to 2019Q4 in the euro area.



Source: ECB Survey of Professional Forecasters (SPF); Last accessed on September 26, 2020; Series name: HICP Inflation forecasts; Available at https://www.ecb.europa.eu/stats/ecb_surveys/survey_of_professional_forecasters/html/table_hist_hicp.en.html.

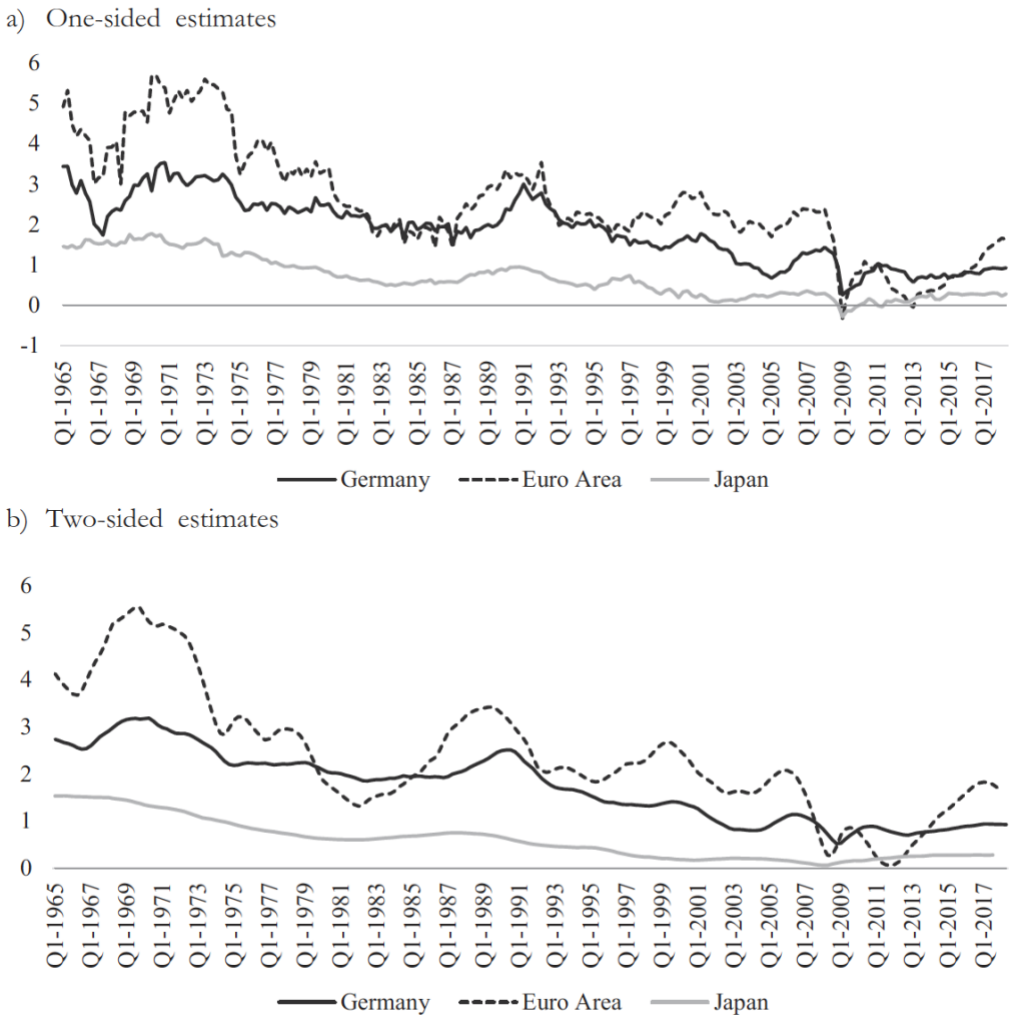
Notes: Quarterly data on five-years-ahead inflation expectations is only available from 2001Q1 onwards.

Figure 11. Estimates of medium-term equilibrium real interest rates in the United States.



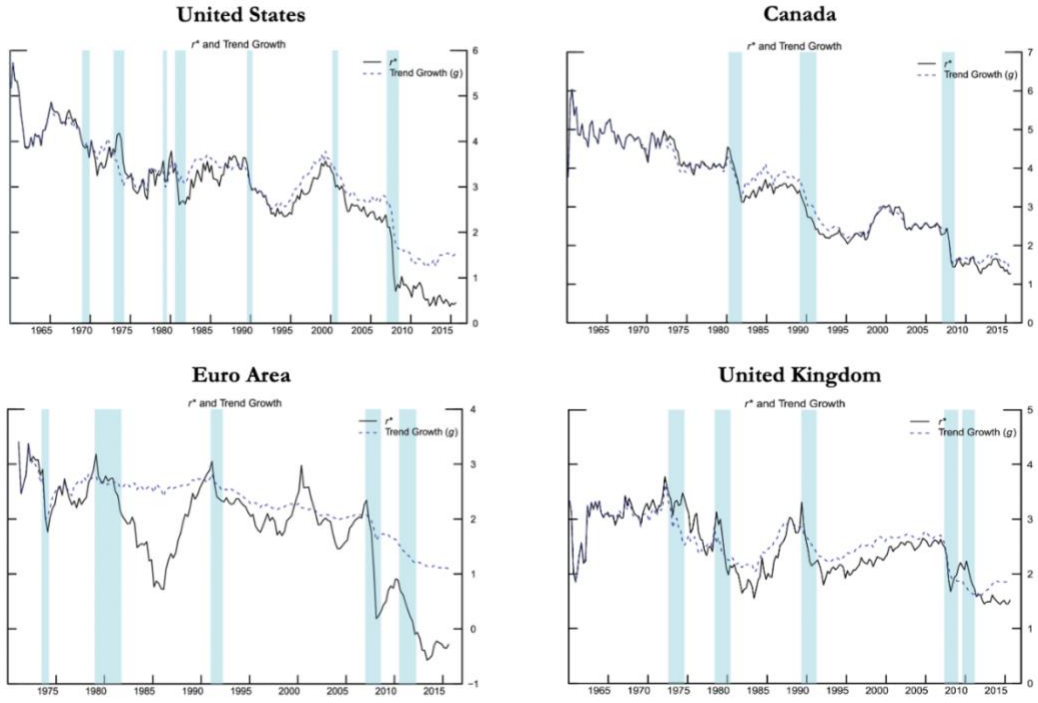
Source: Beyer and Wieland (2019).

Figure 12. Estimates of medium-term equilibrium real interest rates in Germany, the Euro Area, and Japan.



Source: Beyer and Wieland (2019).

Figure 13. Estimates of natural real interest rates and trend GDP growth in the United States, Canada, the Euro Area, and the United Kingdom.



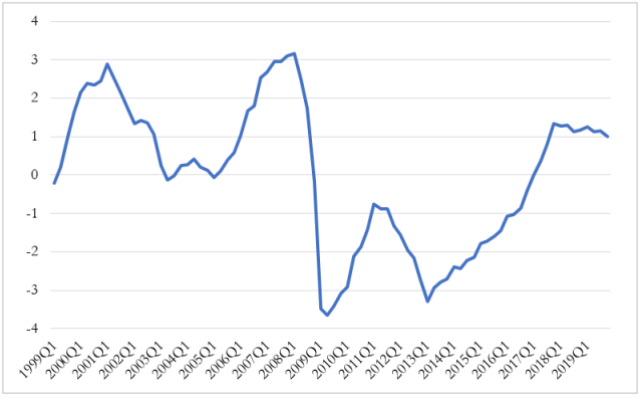
Source: Holston et al. (2017).

Figure 14. Inflation rates in the euro area from 1999Q1 to 2019Q4.

Source: Eurostat; Last accessed on August 20, 2020; Series name: HICP (2015=100) – monthly data (annual rate of change); Available at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_manr&lang=en.

Notes: Autor's calculation; Annual rate of change; All-items HICP.

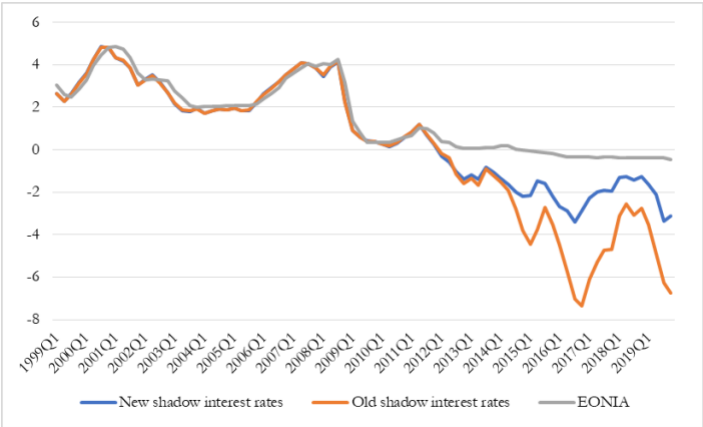
Figure 15. Output gap in the euro area from 1999Q1 to 2019Q4.



Source: Eurostat (for actual real GDP), AMECO database (for potential real GDP); Last accessed on August 20, 2020; Series name: GDP and main components (output, expenditure and income) (actual real GDP), Potential gross domestic product at 2015 reference levels (potential real GDP); Available at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=namq_10_gdp&lang=en (actual real GDP), https://ec.europa.eu/economy_finance/ameco/user/serie/ResultSerie.cfm (potential real GDP).

Notes: Author's calculation.

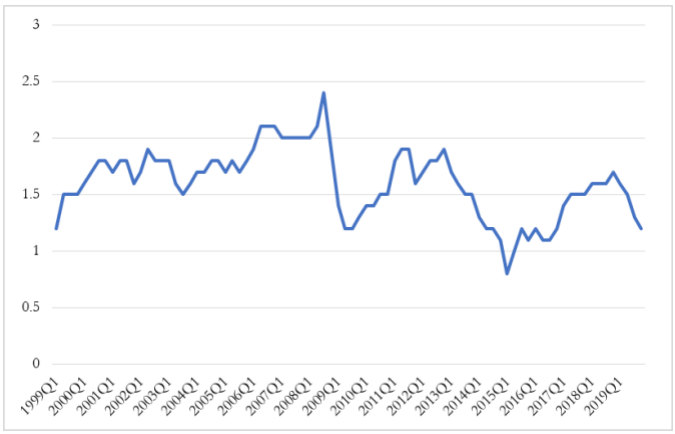
Figure 16. Short-term nominal interest rates in the euro area from 1999Q1 to 2019Q4.



Source: LJKmfa Homepage (for new and old shadow interest rates), ECB Statistical Data Warehouse (for EONIA); Last accessed on August 20, 2020; Series name: International SSR estimates (new and old shadow interest rates), EON – EONIA: Euro Interbank Offered Rate (EONIA); Available at https://www.ljkmfa.com/test-test/international-ssrs/ (new and old shadow interest rates), https://sdw.ecb.europa.eu/browseExplanation.do?node=9689692 (EONIA).

Notes: Author's calculation.

Figure 17. Inflation expectations in the euro area from 1999Q1 to 2019Q4.



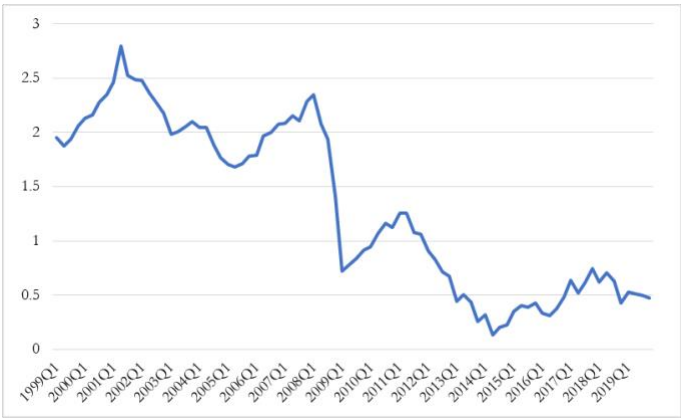
Source: ECB Survey of Professional Forecasters (SPF); Last accessed on August 20, 2020; Series name: HICP Inflation forecasts; Available at https://www.ecb.europa.eu/stats/ecb_surveys/survey_of_professional_forecasters/html/table_hist_hicp.en.html.

Figure 18. Output gap expectations in the euro area from 1999Q1 to 2019Q4.

Source: ECB Survey of Professional Forecasters (SPF); Last accessed on August 20, 2020; Series name: Real GDP growth forecasts; Available at https://www.ecb.europa.eu/stats/ecb_surveys/survey_of_professional_forecasters/html/table_hist_rgdp.en.html.

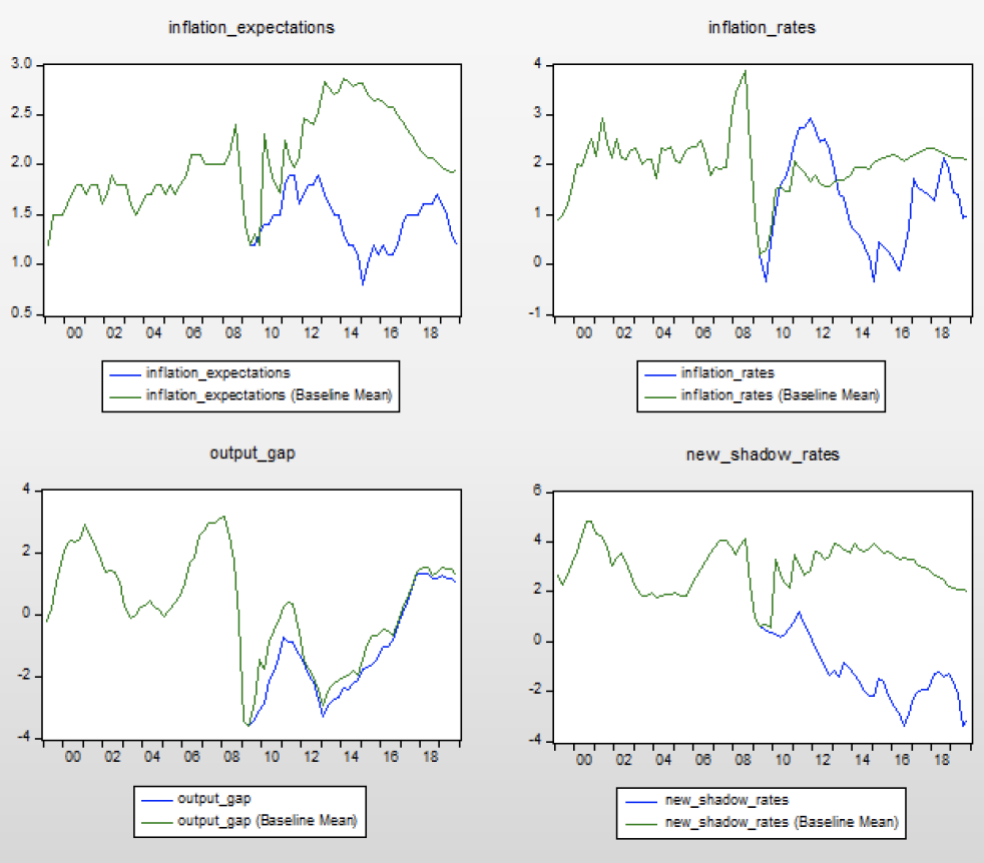
Notes: Author's calculation. Data on both actual real GDP and potential real GDP were also needed to compute output gap expectations.

Figure 19. Natural real interest rates in the euro area from 1999Q1 to 2019Q4.



Source: Federal Reserve Bank of New York; Last accessed on August 20, 2020; Series name: R-star for advanced economies – HLW estimation; Available at https://www.newyorkfed.org/research/policy/rstar.

Figure 20. Simulation results.



Notes: Author's calculations; Simulation output retrieved from EViews; Blue lines refer to the observed values, while green lines refer to the simulated values (green lines before 2009Q3 represent, in practice, the observed values).

6.2 Tables

Table 1. Volatility of inflation rates from 1970Q1 to 2019Q4 in selected OECD countries.

Countries	Sample Period	
	1970Q1-1989Q4	1990Q1-2019Q4
Canada	3.07	1.18
Germany	2.11	1.17
New Zealand	4.44	1.40
United Kingdom	5.83	1.68
G7	3.33	1.07

Source: Organisation for Economic Cooperation and Development (OECD); Main Economic Indicators database.

Notes: Author's calculation based on data plotted in Figure 1; Volatility is measured by the sample standard deviation.

Table 2. Summary of the data.

Variable	Figure	Computed	Source	Original frequency
Inflation rates	14	No, only converted to quarterly data	Eurostat	Monthly
Output gap	15	Yes	Eurostat and AMECO	Quarterly (actual real GDP) and Annual (potential real GDP)
Short-term nominal interest rates	16	No, only converted to quarterly data	Krippner estimates and ECB Statistical Data Warehouse	Monthly (shadow interest rates) and Daily (EONIA)
Inflation Expectations	17	No	ECB's SPF	Quarterly
Output gap expectations	18	Yes	ECB's SPF, Eurostat, and AMECO	Quarterly (growth forecasts and actual real GDP) and Annual (potential real GDP)
Natural real interest rates	19	No	Federal Reserve Bank of New York – HLW estimates	Quarterly

Table 3. Estimates of model parameters and the corresponding p-values.

Parameter	Sample Period			
	1999Q1-2019Q4		1999Q1-2009Q2	
	Estimates	P-values	Estimates	P-values
β	0.988614	0.0000	0.887436	0.0000
κ	0.178250	0.0000	0.290804	0.0006
θ	0.766874	0.0000	0.719103	0.0000
α	0.101953	0.0053	-0.287869	0.0055
λ	4.514620	0.0000	1.550533	0.0173
γ	-0.878436	0.0008	-0.402690	0.1201