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Executive summary of the thesis

NEGATIVE INTEREST RATE POLICY: THEORETICAL BACKGROUND AND EMPIRICAL EVIDENCE ON THE MONETARY TRANSMISSION MECHANISM

Tesi magistrale in Management Engineering (Finance) – Ingegneria Gestionale (Finanza)

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1. Introduction

The goal of this thesis is to provide a comprehensive analysis and assessment of the adoption of Negative Interest Rate Policies (NIRP) so far. This work follows an approach that combines theoretical and empirical considerations, that aim at shedding light on the motivations behind the introduction of NIRP and the main implications and results of this innovative monetary policy tool. The main objective is to contribute to the literature, proposing a structural vector autoregressive model (SVAR) to study, in a structured way, the dynamics of the monetary transmission mechanism to the economy during the negative rates period.

2. Negative Interest Rate Policy: context and motivations

Negative Interest Rate Policy (NIRP) is an unconventional monetary policy tool whereby a central bank sets a nominal negative deposit rate on the excess reserves of commercial banks.
The Danmarks NationalBank has been the first to introduce NIRP, in 2012, followed then by several other central banks. Among these, many took the decision to rely on negative rates with the aim of supporting growth and pushing inflation towards its target, while facing an environment characterised by an ultra-low, if not negative, natural rate of interest. This is the case, among others, of the European Central Bank and the Bank of Japan. The main motivation is, instead, different in case of Denmark and Switzerland, whose central banks cut rates in negative territory in order to fight excessive capital inflows and local currency appreciation.

The infringement of the zero lower bound of nominal interest rates is something innovative in the history of monetary policy. The effective lower bound represents the estimated lower limit that can be reached by nominal rates before assisting to a massive switch from liquid assets into cash. This limit represents the new reference lower bound for central banks, together with the reversal rate, which is the rate at which additional rate cuts can become contractionary for lending.

3. Transmission channels of negative rates

The empirical evidence testifies an effective transmission of NIRP through the financial markets and the banking sector, with some relevant peculiarities compared to standard rate cuts. The main merits of NIRP are essentially two:

I. It removes the non-negativity constraint on current and future short-term rates, playing in this way a key role in shaping agents' expectations, given that accommodative scenarios of negative rates start to be considered realistic.

II. It stimulates a mechanism of portfolio rebalancing, since economic agents in search for yield enhance their risk-taking attitude as answer to negative yields spreading to short-term and less risky assets. This leads to investments in longer-term and riskier assets and, in case of banks, also to increase lending (in the limits of capital requirements). The portfolio rebalancing activity follows also positive rate cuts, but it is particularly relevant facing negative nominal yields.

3.1. Financial markets channel

Looking in detail at the financial markets, we can observe that NIRP has transmitted to short-term money market rates. Excess liquidity, injected by means of asset purchase programs, played a relevant role in the pass-through of the negative policy rate to money markets. In fact, commercial banks found themselves with huge amounts of reserves charged by the central bank. Therefore, they looked for alternative uses and, as a consequence, the high supply of liquidity dragged short-term and interbank rates into negative territory, with overnight rates tracking closely the deposit facility rate in the Euro area.

Negative rates spread also to government bonds, with a large part of the Euro area yield curve moving below zero. The peculiarities of NIRP as concerns the expectations channel and the stimulation of risk taking are the main drivers behind the enhanced effect on medium and long-term maturities. We can indeed notice how the reaction to rate cuts below zero has been quite persistent across maturities, often with a one-to-one transmission of policy rate changes.

The decrease in risk-free rates has a direct effect also on riskier assets, leading to an appreciation of stocks, for example. This dynamics is enhanced by the risk taking channel, which is particularly relevant with negative rates and induces a compression of risk premia.

Furthermore, rate cuts in negative field can affect also the exchange rates, typically depreciating the local currency.

3.2. Banking sector channel

Moving to the banking sector, the traditional interest rate channel seems to work also under NIRP, even though with some concerns.

In line with the general reduction of rates observed in the financial markets, overall bank funding costs decreased following the introduction of negative rates. However, the evidence shows that household deposit rates are characterised by a downward rigidity close to zero, which tends to limit the pass-through. As for corporate deposit rates, the constraint appears instead less strict, probably because of the higher costs that firms would face to switch into cash in case of large amounts.

The imposition of negative rates on corporate deposits, however, did not translate in deposit outflows. This is explained by the fact that healthy banks, relying on the market power guaranteed by their sound balance sheets, can transfer the negative rates to corporate depositors without losing customers, actually experiencing a positive deposit growth, if anything.

Following the standard transmission mechanism, lower funding costs lead to a decrease of loan rates that, in turn, generate an increase of credit demand. This dynamics characterises also NIRP period, even though there is contrasting evidence on the level of pass-through to lending rates compared to conventional rate cuts. Opposing forces coexist and can be responsible of different empirical results according to the methodology and the horizon considered. For example, the zero lower bound on household deposit rates weighs in favour of a restricted pass-through, while the enhanced risk-taking attitude may lead banks to decrease loan rates in order to stimulate lending and compensate the negative charge on excess reserves.

In addition to the interest rate channel, NIRP induces or enhances other mechanisms. As anticipated, the search for yield pushes banks to lend more and sometimes even to riskier borrowers, obviously in a compatible way with regulatory requirements.

Moreover, negative rates spur a new mechanism, the so-called corporate channel. Firms with high liquid assets tend to rebalance their balance sheets towards fixed investments, as answer to the charges typical of the negative environment.

4. Interaction with other monetary policies

The positive contribution of NIRP is not limited to its individual effects, given that this tool shares important complementarities with other unconventional monetary policies.

NIRP and forward guidance reinforce each other since they both act through the expectations channel to affect longer term rates. Asset purchase programs (APPs) are employed to compress long-term rates and their effect is enhanced by NIRP. When the excess liquidity produced by APPs is subject to negative rates, the portfolio rebalancing activity leads to a further compression of term premia.

The concurrent presence of targeted longer term refinancing operations (TLTRO) and NIRP allowed banks to borrow funds at negative rates.

5. Impact on macroeconomic variables

The enhanced accommodative impact on longer maturities, also thanks to the fruitful interaction with other policies, is particularly relevant because long-term rates are a key variable in economic choices. Investments are also spurred by the corporate channel induced by NIRP. The significant appreciation of the main asset classes can stimulate spending and consumption through confidence and wealth effects. In addition, higher asset prices can contribute to an increased collateral value for some borrowers, so empowering the balance sheet channel. The rise of credit origination, both demand and supply driven, supports the economic growth.

6. NIRP potential side effects

Some concerns still remain on the potential side effects of NIRP. First of all, bank profitability has not significantly deteriorated so far but it may be threatened by a more prolonged period of negative rates. The compression of net interest margins is indeed exacerbated when rates move into negative territory and the downward rigidity on household deposit rates limits the easing impact on bank funding costs. Some positive effects produced by NIRP have till now counterbalanced the tighter margins. The revaluation of financial assets on banks' balance sheets translates in capital gains; the improved macroeconomic outlook entails a higher creditworthiness of borrowers that corresponds to lower loan loss provisions; the increased loans demand partially offsets the squeezed margins. However, these positive forces tend to be more temporary than the compression of NIM, rising in this way the concerns in case of persistently negative environments.

Given that profits, through retained earnings, represent an important source for bank net worth, potential issues on profitability may undermine the entire functioning of the banking sector. In fact, commercial banks are subject to strict regulatory requirements and their capitalisation is fundamental to carry on the traditional lending activity.

Furthermore, negative rates may, if anything, aggravate the build-up of financial vulnerabilities, which can undermine the financial stability and the resilience of the system to adverse shocks. Risk mispricing, excessive debt and overleverage, illiquidity and extreme interconnectedness are some of the main criticalities that can interact and reinforce each other through the different sectors involved. Asset markets, the banking sector, non-bank financial institutions and the non-financial sector are tightly linked and may be hit all together in case of systemic contagion after adverse shocks.

7. A SVAR model for the Euro area

After a thorough discussion of the positive effects and the risks connected with NIRP, this thesis work proposes a Structural Vector Autoregressive model (SVAR) as a framework to study the relationship between monetary policy shocks and the economy during the negative rates period. While the impact of NIRP on the financial markets and the banking sector is object of several studies, the link with macroeconomic variables is less documented by specific empirical research [4]. The analysis, focused on the Euro area, has therefore the main goal to assess if the infringement of the zero lower bound has entailed some kind of disruption of the standard monetary policy transmission mechanism.

7.1. Model Specification

The first step in the design of the model is the selection of the variables of interest. We naturally include the main macroeconomic variables, output and prices, proxied by industrial production and HICP. The EONIA rate, which followed the deposit facility rate in negative territory, is the reference used to derive policy rate shocks. The two macro-channels of transmission, namely the financial markets and bank lending, are synthetised respectively by the 10Y yield on Euro area government bonds and by loans to non-financial corporations. A variable representing excess reserves is included given the relevance and the complementarity of this measure with negative rates. Finally, an index of commodity is introduced as exogenous variable, in order to deal with the so called price puzzle.

The focus of the model is on the NIRP subsample, specifically made of monthly observations from 2014:06 to 2020:02, but its robustness is tested also on a longer horizon.
A standard information criterion, such as the Schwarz or Bayesian one, is used to determine the optimal lag, found equal to one.

7.2. Estimation and identification strategy

The estimation of a SVAR model and the univocal identification of structural shocks require the imposition of some identifying restrictions on the matrix representing the contemporaneous interactions among the endogenous variables. We adopt a standard recursive identification, also known as plain Cholesky, that consists basically in assuming a lower triangular contemporaneous matrix. This translates in limiting the immediate impact of structural shocks only to specific variables. The ordering of the variables is the following.

Y = [Output, Prices, Reserves,
EONIA, 10Y Yield, Lending]

Focusing the attention on monetary policy shocks, they do not affect contemporaneously output, prices and reserves, while they have an immediate impact on the transmission channels, i.e. the financial markets and bank lending. We can finally notice that excess reserves are free to directly influence the EONIA rate, as it is reasonable considering that higher available liquidity can generally decrease the applied money market rates.

7.3. Results and discussion

Studying the impulse response functions, we find that easing monetary shocks induce an immediate reduction of bond yields and an increased supply of loans, in line with the extant empirical evidence. Moreover, prices and output react positively to expansionary shocks in negative territory.
These results testify an unimpeded pass-through of monetary policy to the economy, providing a confirmation to the thesis that the transmission mechanism is robust to the infringement of the zero lower bound.
However, some non-negligible limitations of the model deserve to be discussed. The reduced size of the NIRP subsample definitely threats the robustness of the estimates and leads to quite large confidence intervals. For this reason, while the qualitative interpretation proves to be consistent also on longer horizons, the quantitative assessment of the effects of monetary shocks during NIRP requires longer time series to be considered accurate and reliable. In addition to this issue, the application of VAR models to restricted time spans complicates the recognition of non-stationarity and trend components, which can mix up with cyclical movements. For sure, the economic sense can help for this, but the complexity merits however to be mentioned.

8. Conclusions

We think that, despite the relevant limitations, the proposed SVAR model is able to confirm the additional room of manoeuvre for policy easing stances guaranteed by NIRP. There is no evidence that the infringement of the ZLB has implied a disruption of the standard transmission mechanism.
The analysis of the extant empirical evidence and the framework presented in this thesis lead to the conclusion that NIRP merits to be considered a valid monetary policy. Negative Interest Rate Policies therefore deserve to be certainly part of central banks toolkit, even though some (natural) concerns still remain and should be continuously monitored.

9. Essential bibliography

[1] Arteta, C., M. A. Kose and T. Taskin (2016), "Negative interest rate policies: Sources and implications", *Policy Research Working Paper* 7791*,* The World Bank.

[2] Brandao-Marques, L., M. Casiraghi, G. Gelos, G. Kamber and R. Meeks (2021), "Negative Interest Rates: taking stock of the experience so far", *IMF Departmental Papers / Policy Papers* 2021/03*,* International Monetary Fund.

[3] Peersman, G. and F. Smets (2001), "The monetary transmission mechanism in the Euro area: more evidence from VAR analysis", *Working Paper Series 0091, European Central Bank.*

[4] Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, A. S. Guilhem and J. Yiangou (2019), "A Tale of Two Decades: The ECB's Monetary Policy at 20", *ECB Working Paper No. 2346*.

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Negative Interest Rate Policy:
theoretical background and empirical evidence
on the monetary transmission mechanism

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A chi per me c’è sempre stato

e so che ci sarà sempre.

Abstract

The remarkable decline of the natural rate of interest, set in a context of sluggish growth and disappointing inflation, led several central banks to introduce Negative Interest Rate Policies (NIRP), in search for further room of manoeuvre for policy easing. This thesis proposes a thorough assessment of the experience with NIRP so far. The analysis relies on a combined approach made of theoretical considerations and discussion of the empirical evidence. Moreover, a Structural Vector Autoregressive model (SVAR) is proposed as a basic framework to study the relationship between monetary policy and the economy during the negative rates period. The results of this econometric application confirm that the infringement of the zero lower bound has not caused a disruption of the standard transmission mechanism of monetary policy. In conclusion, the critical review of the empirical evidence and the suggested framework lead to a positive assessment of NIRP and explain why this innovative monetary policy tool deserves to be part of central banks' toolkit, although some concerns regarding bank profitability and financial stability should be continuously monitored.

Key-words: Negative Interest Rate Policy (NIRP), monetary policy transmission mechanism, financial markets, banking sector, Structural Vector Autoregressive model (SVAR)

Sommario

Il significativo declino del tasso naturale di interesse, inserito in un contesto di crescita stagnante e inflazione deludente, ha portato diverse banche centrali a introdurre una politica di tassi di interesse negativi (NIRP), alla ricerca di libertà di manovra addizionale per effettuare politiche espansive. Questa tesi mira a fornire un'approfondita valutazione dell'esperienza con NIRP fino ad oggi. L'analisi si basa su un approccio che combina considerazioni teoriche e discussione dell'evidenza empirica. Inoltre, viene proposto un modello vettoriale autoregressivo strutturale (SVAR) come framework per studiare la relazione tra politica monetaria ed economia durante il periodo di tassi negativi. I risultati di tale applicazione econometrica danno conferma del fatto che la violazione dello Zero Lower Bound non ha causato un sovvertimento del meccanismo standard di trasmissione della politica monetaria. In conclusione, la rassegna critica dell'evidenza empirica e il modello proposto portano a una valutazione complessivamente positiva delle politiche di tassi negativi e spiegano perché questo innovativo strumento meriti di far parte del toolkit delle banche centrali, per quanto alcune questioni riguardanti la profittabilità del settore bancario e la stabilità finanziaria debbano essere continuamente monitorate.

Parole chiave: Politica di tassi di interesse negativi (NIRP), meccanismo di trasmissione della politica monetaria, mercati finanziari, settore bancario, modello vettoriale autoregressivo strutturale (SVAR)

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Introduction

The Great Financial Crisis aggravated the decline of the natural rate of interest, induced also by structural factors, such as debt accumulation, demographic changes, income inequality and lower productivity growth, which are responsible of severe imbalances between savings and investments. In the aftermath of the 2008 crisis, major central banks reached the zero lower bound of nominal policy rates, in some cases also because of the additional pressure due to the Sovereign Debt Crisis. Facing the necessity to support growth and spur inflation, central banks began to adopt non-standard monetary policies, such as forward guidance and asset purchase programs. However, the zero lower bound was still perceived as a limiting constraint for additional policy easing. Given the very low (often negative) level reached by the natural rate and the sluggish inflation, negative nominal rates started to be considered as something necessary by several central banks. In fact, in order to effectively put in place expansionary monetary policies, the real policy rate (nominal policy rate adjusted for inflation) should be below the natural rate. In the described environment, nominal rates close to zero, but positive, were no more sufficient to reach central banks objectives.

Section 1 of this thesis presents in detail the context and the motivations which led to the introduction of Negative Interest Rate Policy (NIRP), an unconventional monetary policy tool that consists basically in setting a negative rate on the excess reserves of commercial banks deposited at the central bank. While real rates have been negative in several historical periods in the past, nominal negative rates represent an innovative measure, which infringes the zero lower bound, traditionally considered uncrossable. For this reason, the implications and the effects of this monetary policy tool deserve to be deepened from a theoretical and empirical point of view.

Section 2 deals exactly with this. First, it introduces the general dynamics of pass-through of monetary policy, emphasizing the peculiarities that NIRP may present across the different transmission channels. Then, the theoretical considerations are tested collecting the main empirical results of negative rates on the two macro-channels of transmission, the financial markets and the banking sector. Moreover, in addition to the individual effects of NIRP, section 2 focuses on the precious complementarities that this tool shares with the other unconventional monetary policies. Finally, the chapter concludes with an analysis of the impact of negative rate policies on the main macroeconomic variables, namely output and inflation.

Section 3 highlights potential side effects that characterise in general low rates environments, but may be, if anything, exacerbated by negative rates. Therefore, this chapter explores the possible role of NIRP in fuelling financial vulnerabilities, such as risk mispricing, interconnectedness, overleverage and debt accumulation, that may represent a threat for financial stability.

Section 4 proposes a structural vector autoregressive model (SVAR) as a baseline framework to study the relationship between monetary policy shocks and the economy during the NIRP period. In fact, while the effects of NIRP on the financial markets and the banking sector are covered by a quite rich empirical literature, the studies that document in a structured way the link with the macroeconomic variables are limited. The goal of the econometric application in this section is to connect all the pieces in a comprehensive model, in order to assess the robustness of the transmission mechanism of monetary policy following the introduction of negative rates.

The last part of the thesis concludes summing up the main concepts and results illustrated in the four sections. The aim is to provide a condensed but thorough overview of the experience with NIRP so far, relying on both the evidence from the empirical literature and the contribution of the SVAR model proposed and discussed in section 4.

Chapter 1: Negative Interest Rate Policy

1.1. Definition

The term Negative Interest Rate Policy (NIRP) refers to an unconventional monetary policy tool whereby a central bank sets nominal target interest rate below zero. More specifically, the key policy rate object of this decision is mainly the deposit rate, the percentage interest paid on excess reserves held by commercial banks at the central bank. When this rate enters in negative territory, it means that commercial banks are paying to keep deposits at the central bank or, in other words, that the central bank is charging depositors holding inactive excess reserves.

The deposit rate is a particularly relevant measure because it influences the rates paid by commercial banks on deposits of households and corporations and also the interests charged on loans in the interbank, consumer and business markets. Moreover, it is a determinant of the level of the risk-free rate and, as a consequence, it affects the yield curve and, in turn, also riskier assets in the financial markets.

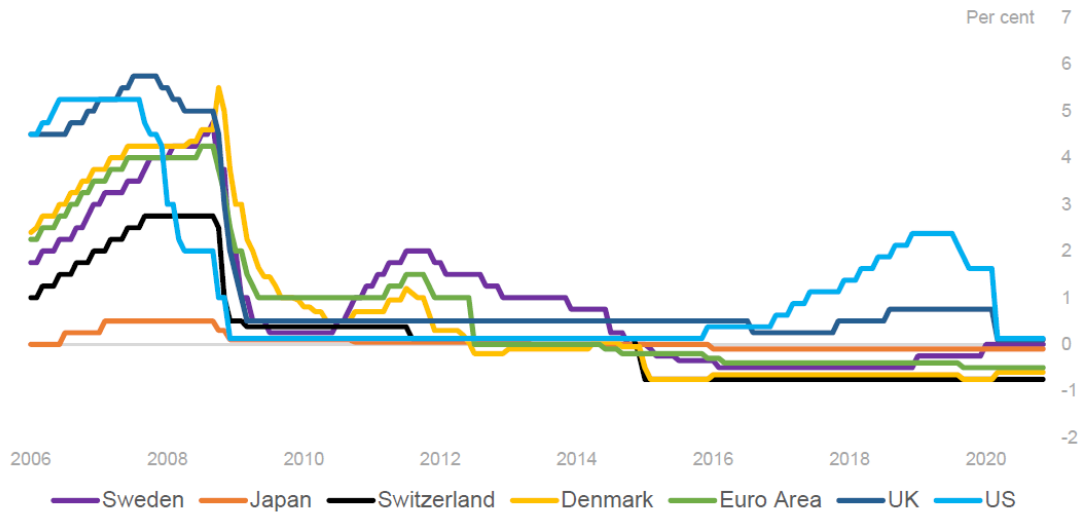
1.2. History of negative rates

Several central banks decided to cut interest rates till negative levels in the years after the 2008-09 Financial Crisis, starting in 2012 with the Danmarks NationalBank, which set its one-week deposit rate below zero. After that, also the ECB brought its deposit facility rate into negative field in June 2014, followed by other European national banks. Among these countries, we can mention Switzerland, Sweden, Norway[1] and also some cases in the Eastern Europe such as Hungary, Bulgaria and Bosnia and Herzegovina. Moreover, outside Europe, NIRP has been adopted by Japan since January 2016. Other large central banks, such as the Federal Reserve and the Bank of England, instead, have never infringed the zero lower bound for their benchmark rates (Figure 1.1).

[1] Actually, in the case of Norway, the key policy rate (the overnight deposit rate) has never gone below zero, but the reserve rate on deposits above a certain threshold has (Malovana et al. 2020)

These different decisions can be understood recognising that the effects of monetary policies can vary across countries and over time because of specific factors of differentiation. Among these, we can mention the structure of the financial system, for example in terms of banks' balance sheets composition, the openness and largeness of the different economies, the level and the characteristics of households' debt.

Figure 1.1: Advanced economies policy rates

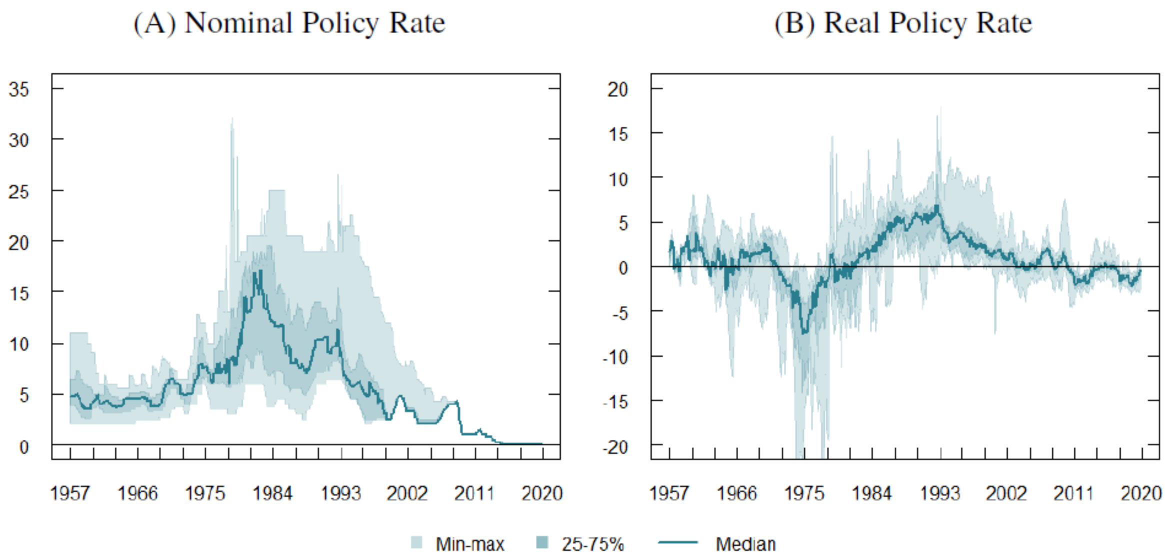


Notes. Sweden: repo rate. Japan: target for uncollateralised overnight rate until December 2015; rate on Complementary Deposit Facility thereafter. Switzerland: average of SNB target range until June 2019, SNB policy rate thereafter. Denmark: certificate of deposit rate. Euro Area: rate on main refinancing operations until May 2012, deposit facility rate thereafter. UK: Bank Rate. US: average of range for Fed funds rate.

Source: Tenreyro (2021)

The wave of negative interest rate policies described above is something new in the history of monetary policies. Apart from a few exceptions, such as Japan during the downturn of the late 1990s (Arteta et al. 2016), *nominal* interest rates have always moved above zero. The picture is different if we look at the *real* ex-post policy rate, that has been negative in several historical periods (see Figure 1.2, panel B, referring to the Euro area), overall for approximately one third of time between 1957 and 2019 (see Table 1.1, Real CB Policy Rate, column "Total"). For example, in the 1970s, real rates were massively negative because of the large inflationary shocks that characterised those years. The key difference is that, in recent years, in presence of weak inflation, the ultra-low nominal rates set by central banks became the main determinant of negative real rates.

Figure 1.2: Nominal and Real rates in the Euro area



Note. The real policy rate is calculated as the nominal policy rate minus actual consumer inflation.

Source: Malovana et al. (2020)

Table 1.1: Percent of time policy rates have been zero or negative

	Nominal CB policy rate			Real CB policy rate		
	Total	Before 2008	2008+	Total	Before 2008	2008+
Euro area	8	0.0	31.5	39.8	28.7	71.6
Other European countr.	4.5	0.0	16	32.7	25.2	50.9
Asia	2.3	2.2	2.5	30.4	25.7	37.8
US	0.0	0.0	0.0	31.7	20.7	81.1
Canada	0.0	0.0	0.0	27.2	13.3	83.1
Japan	10.9	7.8	27.3	38.8	34.3	61.3

Note: Frequency calculated as number of months when central bank policy rate was zero or negative divided by total number of months, in percent. Time period: 1M 1957–11M 2019. Euro area: AT, BE, CY, FI, FR, DE, GR, IE, IT, MT, NL, PT, SI, SK, ES. Other European countries: CZ, DK, HU, IS, NO, PL, RO, SE, CH, UK. Asia: CN, IN, ID, IL, JP, KR, MY, PH, RU, TH, TR.

Source: Malovana et al. (2020)

Summing up, real interest rates, that are the reference measure to avoid the so called monetary illusion, have often been negative. However, the level of the nominal rates and the persistency of negative real rates in recent years (Table 1.1, Real CB Policy Rate, column "2008+") are among the key variables to monitor.

Another interesting aspect to deepen is the existence of lower bounds for policy rates, a topic more and more studied given the recent environment.

1.3. Interest rates lower bounds

The zero lower bound (ZLB) is the limit historically considered for nominal rates in many works and textbooks, following the argumentation of Hicks (1937): *"If the costs of holding money can be neglected, it will always be profitable to hold money rather than lend it out if the rate of interest is not greater than zero. Consequently the rate of interest must always be positive."*

The pitfall of this statement is exactly the initial assumption: the costs of holding money actually cannot be neglected in real world, in particular in case of huge amounts of cash. The existence of insurance and storage costs means that the nominal return to large amounts of cash can be negative (IMF, 2021). This is why it is possible for central banks to set negative deposit rates without incurring in a significant cash hoarding phenomenon.

However, interest rates are actually bounded by a technical minimum, the so called effective lower bound (henceforth ELB). IMF (2021) defines it as "*the interest rate below which there would be a move away from assets that carry nominal interest charges into cash, which is always redeemable at its nominal face value*". Taking into account the cost of storing and holding physical cash, the ELB is generally located below zero in advanced economies, as shown in the summary table (Table 1.2) by IMF (2021).

Table 1.2: Estimates of the Effective Lower Bound

Country	Estimate (percent)	Source
Canada	−0.25 to −0.75	Witmer and Yang (2015)
Czech Republic	−0.2 to −0.6	Kocunová and Havránek (2018)
Denmark	−1.5	Rostagno and others (2016)
Euro area	−0.7	Rostagno and others (2016)
Sweden	−1.6	Rostagno and others (2016)
Switzerland	−0.5	Rostagno and others (2016)
United States	−0.35	Burke and others (2010)

Source: IMF (2021)

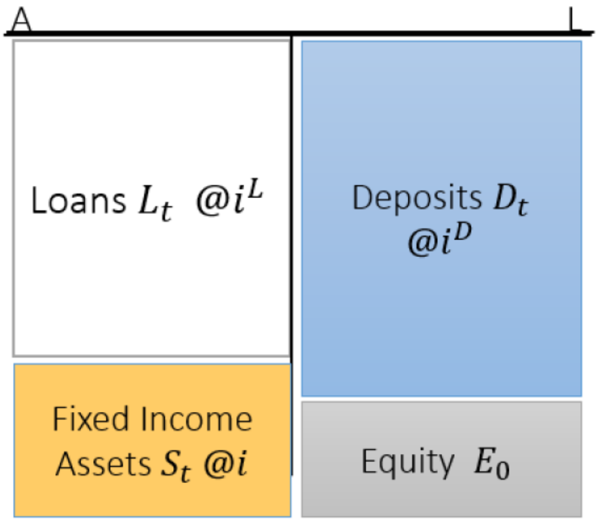
To conclude the overview regarding the limits for negative rates, there is another concept that central banks have to keep under monitoring, the "reversal rate". It is defined by Brunnermeier and Koby (2018) as "*the rate at which accommodative monetary policy reverses its intended effect and becomes contractionary for lending*". Formally, this can be represented as follows:

1. $i > i^{RR}$ *implies* $\frac{dL^*}{di} < 0$;
2. $i = i^{RR}$ *implies* $\frac{dL^*}{di} = 0$;
3. $i < i^{RR}$ *implies* $\frac{dL^*}{di} > 0$.

The interpretation is that a rate cut has an expansionary effect on lending provision if and only if the current nominal policy rate is above the reversal rate i^{RR}, while on the opposite case the rate decrease may result to be even contractionary. In practice, the issue is that too low interest rates may have adverse effects on financial intermediaries and credit dynamics, leading to impairment or reversal of policy rates pass-through to lending and deposits rates (IMF, 2021). Brunnermeier and Koby (2018) explain in deep how the mechanism works: among the key factors underlying the reversal rate we have the composition of financial intermediaries' balance sheets and income and their capitalisation in relation with regulatory constraints. In particular, the existence of the reversal rate "*relies on the net interest income of banks decreasing faster than recapitalization gains from banks' initial holdings of fixed-income assets.*"

To discuss the model described by Brunnermeier and Koby, it is useful to start from the simplified balance sheet of a bank (see Figure 1.3). Among the assets, we have Loans, that is the variable of interest according to the formal definition of reversal rate reported above, and Fixed Income Assets, such as Bonds. The liabilities are divided into Deposits and Equity.

Figure 1.3: Bank stylised balance sheet



Source: Brunnermeier and Koby (2018)

A rate cut implies two main opposing forces affecting banks' net worth: a positive effect in terms of capital gains due to the revaluation of fixed-rate bonds, but also a negative impact[2] on the net interest income, because of thinner interest margins[3]. Problems rise when the negative force is larger in magnitude than the benefit, leading to a squeeze of profitability

[2] The simplified version of the model does not consider the potential increase of credit demand due to the rate cut.

[3] This is particularly true at ultra-low or negative interest rates. In fact, we will see that retail deposits are subject to a downward rigidity, in particular near the ZLB, that causes a tightening of margins if loan rates are instead adjusted to the rate cut.

with the consequent negative impact on equity capital through lower retained earnings. This, in turn, implies less resources to face regulatory constraints and may lead to the necessity to reduce lending in order to respect capital ratios. This is how a rate cut below the reversal rate may be responsible of a contraction of lending.

From the previous mechanism, it is clear that some variables have a crucial role on the level of the reversal rate and on credit emission dynamics.

- As for the composition of the balance sheet, if a bank is more exposed to long-term fixed-rate bonds, it would have a higher benefit from the revaluation of these assets. As a consequence of this mechanism, a larger maturity mismatch translates in a lower reversal interest rate. In fact, if the squeeze of net interest margins is counterbalanced by significant capital gains, then there is more room for rate cuts, before reaching a point where this action becomes contractionary for lending.
- Weak capitalisation and strict regulatory constraints are, instead, factors that tend to ease the contraction of lending following a drop in profitability.
- The duration of a rate cut is another subtle aspect to consider: "*Low for Long rate environments can depress lending*." This statement by Brunnermeier and Koby (2018) is based on the observation that the negative impact on banks' net interest income may last much more than the revaluation gains. In fact, while the latter tend to exhaust in the short-term, the former can extend over time if the rates are kept at the low levels they have reached.

In conclusion, since the reversal rate represents a separated concept with respect to the effective lower bound and may be higher or lower than the ELB, it is important to monitor both measures when studying monetary policy decisions.

1.4. Context and Motivations for negative rates

Several factors should be considered in order to explain the decision by several central banks to cut policy rates to negative levels. A key measure that is influenced by these factors and deserves a thorough analysis is the *natural rate of interest*. This can be defined as the equilibrium short-term real rate consistent with actual output equalling potential one and stable inflation (Laubach and Williams, 2003).

Interpreting this definition through the lens of the *Philips curve*, we can notice that in correspondence of the natural rate we have the potential output and so also the natural rate of unemployment: since the latter is identified as the NAIRU (Non-Accelerating Inflation Rate of Unemployment), when $u_t = u_n$ in equation (1.1) we have also stable inflation ($\pi_t = \pi_{t-1}$).

$$\pi_t - \pi_{t-1} = -\alpha * (u_t - u_n) \qquad (1.1)$$

1.4.1. The natural rate of interest

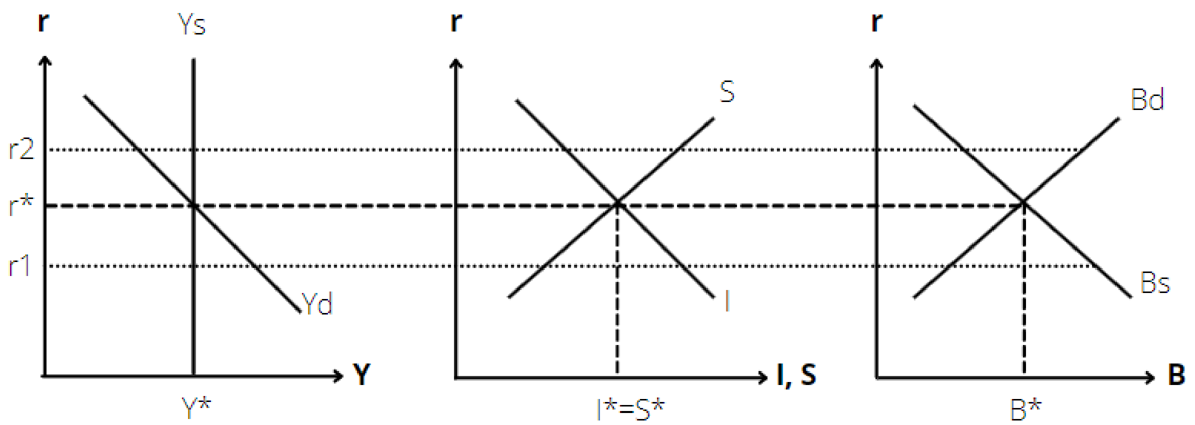
The natural rate of interest is not directly observable, but it can be estimated: its evolution is always monitored since it represents a key reference point for monetary policy decisions. As explained by Amato (2005), the natural rate is an important benchmark for central banks when setting nominal policy rates: in fact, the difference between the realised real interest rate and the natural rate is what defines if a policy is accommodative or if it is a tightening. This concept is stressed also by Laubach and Williams (2003) and Malovana et al. (2020): if the real short-term rate, i.e. the monetary policy rate adjusted for inflation, is below the natural rate, the policy is considered expansionary; instead, if the real rate is above the natural rate, the policy is said restrictive. This dynamic is expressed also in monetary policy rules such as the Taylor rule, in which a rate higher than the natural is fixed as a tightening answer to an excessive inflation compared to target.

In addition, to be more precise, Amato (2005) underlines that spending and investment decisions are more influenced by longer-term rates, so the key variable to monitor for central banks is the deviation of real long-term rate from the "long term natural rate" (where the latter is derived by means of future expected short-term natural rates). For this reason, it is evident the pivotal role played by expectations (about the future path of policy rates and inflation) that affect long-term rates.

The seminal work regarding the natural rate of interest is the one by Wicksell (1898), who defined the natural rate as the rate of interest that equates *saving* with *investment*.

This definition is coherent with and well represented by the neoclassical model shown in Figure 1.4: the natural rate r* is the real interest rate that corresponds to the equilibrium both in goods and bonds market. When the rate is $r_2 > r^*$, we are in a situation of lack of demand compared to natural output and excess of savings (bonds demand) with respect to investments (bonds supply). The opposite is true in case the actual rate is $r_1 < r^*$.

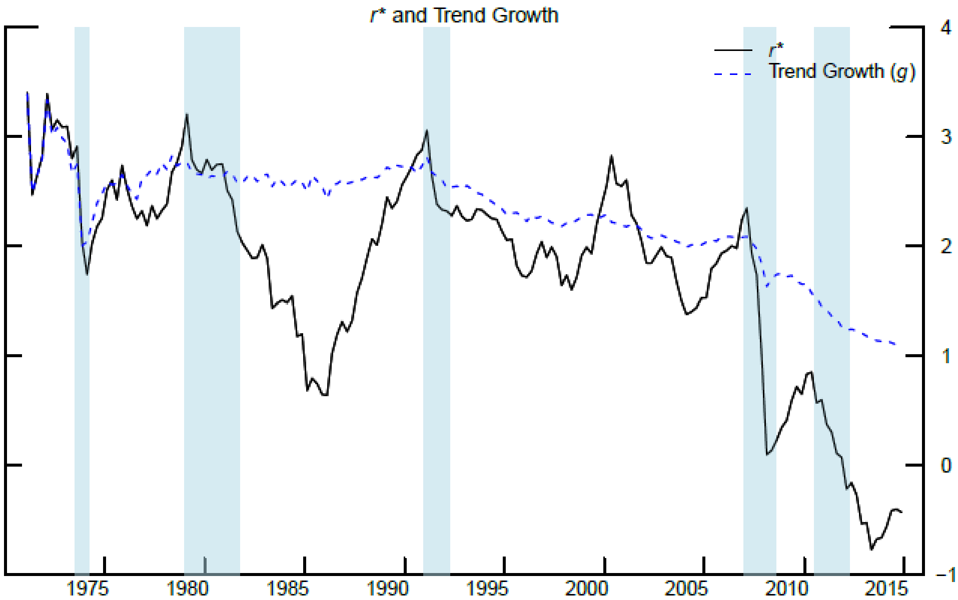
Figure 1.4: The natural rate of interest in the Neoclassical model



Source: Author's representation

What is particularly interesting in the discussion about NIRP is the declining trend of the natural rate till ultra-low levels. In fact, a very low or negative neutral rate (see Figure 1.5 for the estimated r* in the Euro area) is a key driver to explain the necessity of low real rates to put in place accommodative monetary policies. In an environment with weak inflation and also depressed inflation expectations, the required very low level of real rates translates into the need to set ultra-low nominal policy rates, that became even negative in some cases.

Figure 1.5: Estimation results of r for Euro area*



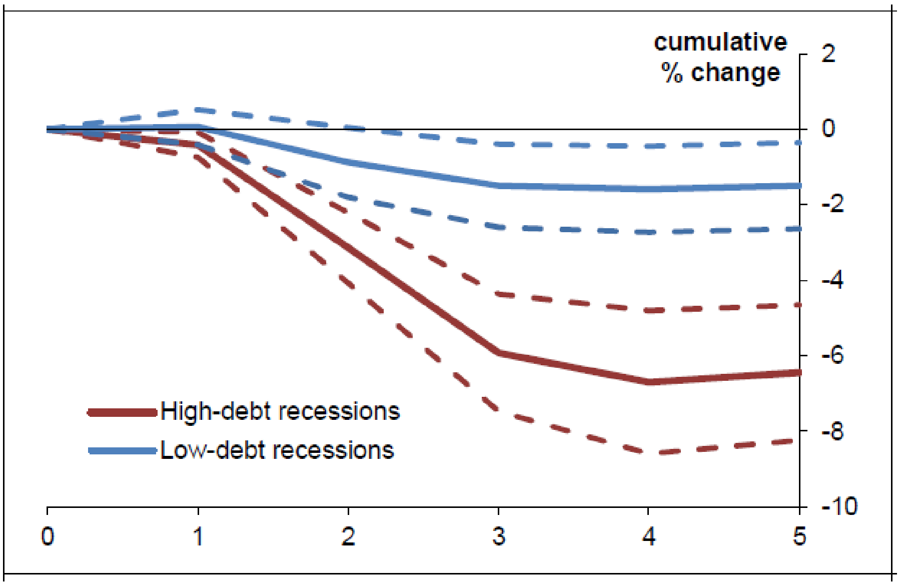
Source: Holston, Laubach and Williams (2016)

Different streams of research have proposed possible explanations for the large decline of natural (and real) rates from the 1980s. According to the first view, known as "Wicksellian", adopted among others by Laubach and Williams (2003), the fall in natural rates is driven by *structural factors* responsible of the imbalance between savings and investments. Among the factors leading to a low rates environment, Vlieghe (2016) identifies three main categories (not completely exhaustive), interacting one with each other, that he calls the 3 D_s.

I. *Debt*: Vlieghe highlights that recessions preceded by a substantial build-up in debt are more severe and longer-lasting. In Figure 1.6 it is shown how households consumption drops consistently more as a result of high-debt recessions.

   This happens because the debt deleveraging process entails cuts of spending, that reflect in deflationary pressures. Policymakers, who desire to sustain growth and want inflation close to target, have to take into account this phenomenon and to be prone to set low interest rates in order to not aggravate the debt burden.

Figure 1.6: Household consumption during years from start of recession, by indebtedness

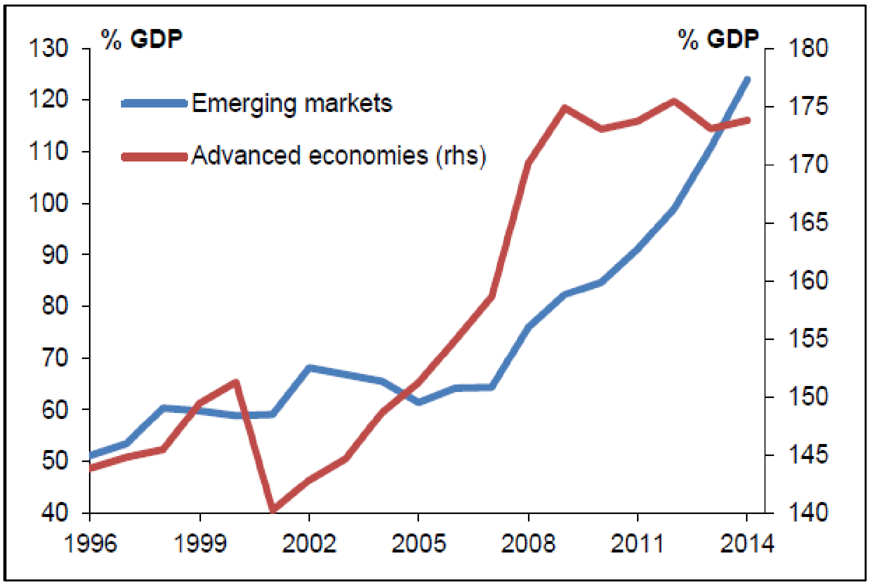


Source: Vlieghe (2016), data from IMF WEO (2012)

The Great Financial Crisis has been anticipated by massive private debt accumulation (Figure 1.7 depicts the growth of private debt as a percentage of GDP, both in case of advanced economies and emerging markets) and the drop in income produced a debt overhang. Borrowers react to that kind of situation cutting spending; central banks have to counteract lowering interest rates, possibly as much as needed to facilitate the debt burden reduction. This would require having rates (loan rates) lower than aggregate income growth, so that the debt-to-income ratio is gradually reduced. The evident complexity is due to the fact that aggregate income growth tends to be a few per cent per year in main economies. This is why negative policy rates may be necessary to drag loan rates as close to zero as possible.

Summing up, it is possible to conclude that higher debt burdens and excessive leverage tend eventually to reduce aggregate investment demand (investment curve shifts to the left in Figure 1.4, graph in the middle).

Figure 1.7: Private sector debt to GDP



Source: Vlieghe (2016), data from IMF GFSR (2015)

II. *Demographics*: longevity has increased and fertility has reduced. Population is growing more slowly, in particular in the advanced economies, and most of all the growth of people in the working age has declined. Less additional workers require less machines and plants, leading to lower investment demand (investment curve shifts to the left in Figure 1.4, graph in the middle).

People live longer but retirement age has not risen in a commensurate way. This means that people have to face more years living with their pension and for this reason they tend to save more during their working life. On the opposite, the increase of the dependency ratio (equal to number of retirees divided by number of workers) means that there are less people with higher savings rates (workers save more than retirees). However, according to experience and research, the overall effect of these forces has been a right shift of the saving curve in Figure 1.4 (graph in the middle).

III. *Distribution of income*: there is evidence that the rich save more and have a lower marginal propensity to spend (e.g. Dynan et al., 2004). As a consequence, the rise of income inequality with important shifts of wealth toward the richest segments has produced an overall higher saving appetite.

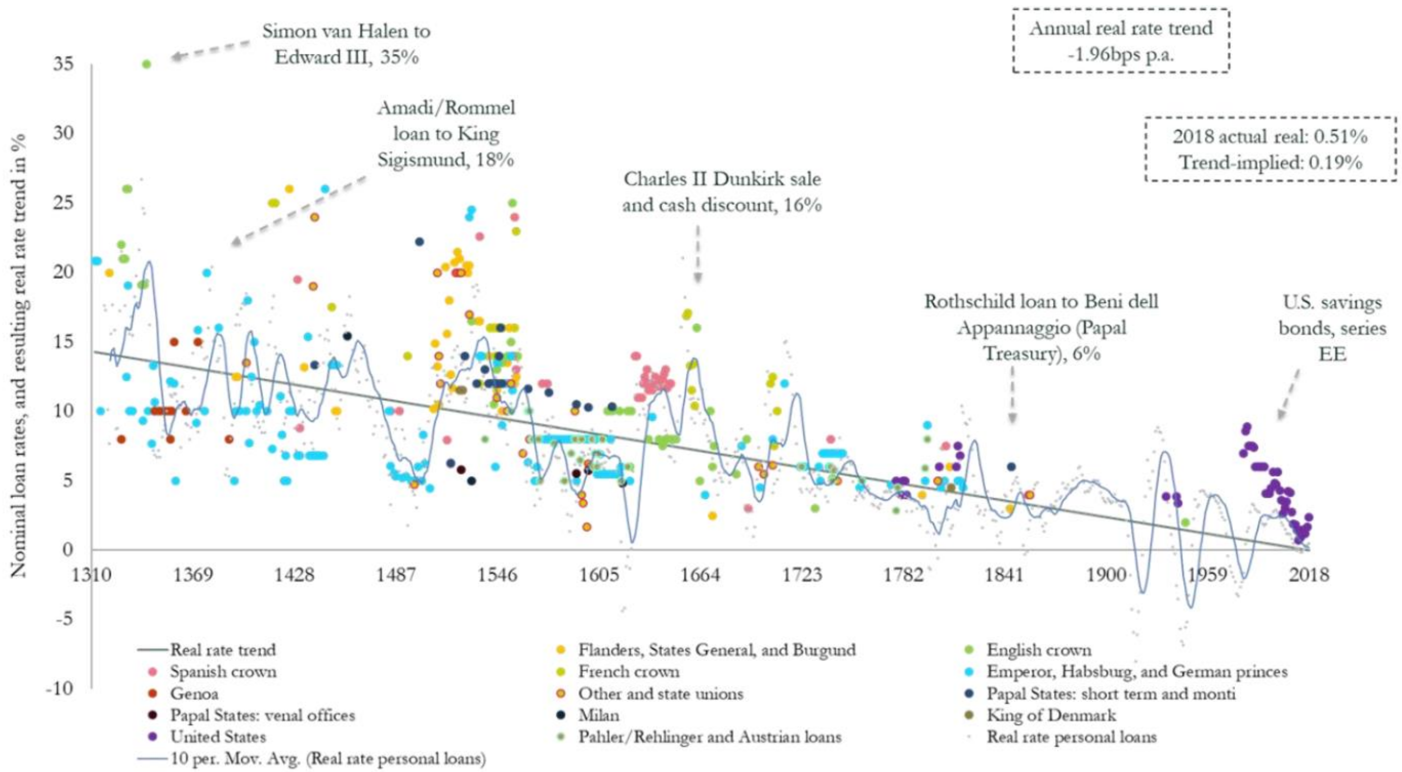
In addition to the 3 D_s, it is worth mentioning at least another driver, presented for example by Malovana et al. (2020).

IV. *Lower productivity growth* has the main effect of reducing the set of profitable investment opportunities but it also spurs saving: since households see a reduced future expected income growth, in an intertemporal perspective they prefer to moderate current consumption to increase saving.

Also Rachel and Summers (2019) argue that changes in saving and investment propensities are the key determinants of the decline of natural rates of at least 300 bps over the last generation. The authors place much emphasis on the concept of *secular stagnation*: according to this narrative, private investment fails in fully absorbing private saving due to structural forces, leading to so low neutral interest rates that monetary policy struggles in contrasting sluggish growth and inflation below target.

This seems exactly what has happened over the last years after the GFC, but Schmelzing (2020) shows also a different perspective considering a much longer time horizon. The author explains that global real rates have been characterised by a persistent suprasecular downtrend over the past centuries (see “Real rate trend” in Figure 1.8) and the decline in real rates since the 1980s may be just a return to long-term historical trends. Schmelzing also argues that long-term real rates were expected to hit zero or lower bounds around the late 20th or early 21st century if correctly framed in a longer-term historical context. Under this view, the secular stagnation hypothesis may appear misleading if stressing the idea of recent savings-investments dislocations as an unusual aberration of longer-term dynamics.

Figure 1.8: Suprasecular declining trend of real rates



Source: Schmelzing (2020)

A different approach to explain the drivers behind the natural rates is the one developed by Juselius et al. (2016) and reproposed by Malovana et al. (2020). The focus in this case is on *cyclical factors*, in particular the role of monetary policy. In fact, the idea is that monetary policy may be not neutral in the medium-long term since it can permanently affect output and real rates through the financial cycle. For this reason, structural factors may be not enough to correctly evaluate the natural rate of interest and financial factors, such as leverage, are accounted in the estimation of r*. The relevance of this approach can be favoured by the increasing financialization of advanced economies since the 1970s and by the significant leverage that may exacerbate the length and depth of financial crisis.

Summing up, what is common to all views is the fact that interest rates may remain at low or negative levels for several years. Schmelzing (2020) is even more drastic stating that there is no reason to expect rates to "plateau", given that their decline is a centuries-long matter and is due to complex combinations of forces persistently present.

1.4.2. Depth of crisis and slow recovery

In the previous paragraph we have mapped out the preeminent role of the natural rate of interest in order to understand the very low rates environment that persists since the years of the GFC. As anticipated before, the 2008-2009 crisis has contributed significantly, together with the other factors illustrated, to pave the way to negative rates. In fact, overlapping to other slow-moving forces, it worsened the investment-saving imbalance, exacerbating in this way the neutral real rates decline.

In these settings, policymakers had to intervene strongly with easing policies in order to contain the negative and dangerous effects of the financial crisis. Facing low natural rates, central banks reached the zero lower bound of nominal interest rates in the years following the GFC. The rise of the sovereign debt crisis also contributed to the urgent need of accommodative monetary policy.

Arteta et al. (2016) argue that, given the context of stagnation, continued growth disappointments and depressed inflation expectations, NIRP was seen as something necessary and useful to provide additional monetary easing. In fact, as explained more in detail in Chapter II, NIRP allows to relax the perceived constraint of the ZLB and also share some complementarities (Rostagno et al. 2019, IMF 2021) with other unconventional tools.

1.4.3. Additional motivations

The need to support growth and spur inflation have generally played a primary role in leading to NIRP in the previously described context. For example, the ECB press release in March 2016 mentions exactly these goals as drivers of the rate cuts into negative territory: *"further ease financing conditions, stimulate new credit provision and thereby reinforce the momentum of the euro area's economic recovery and accelerate the return of inflation to levels below, but close to, 2 percent".*

However, in some cases, other additional causes were decisive for the arrival on the scene of negative rate policies. For example, SNB and DNB (Swiss and Danish national banks) cut rates to negative values to contrast the appreciation of local currencies against the euro and the increasing capital inflows. Too strong Swiss Franc or Danish Krone may represent a serious threat for the competitiveness of the respective countries, in particular as regards the affordability of their exports respect to foreign rivals. This is why central banks enter the game through foreign exchange interventions and/or interest rate adjustments.

The relationship between interest rates and exchange rates deserves a brief discussion: exchange rates are influenced and determined by several drivers, among which also the interest rates related to the two considered currencies. A currency characterised by a higher interest rate (e.g. rate on Swiss government bonds in Franc) is, ceteris paribus, more attractive than the other. This is the concept behind the so called carry trade activity, a speculative practice that consists in selling a low interest rate currency in order to buy assets denominated in a currency that guarantees a higher rate; the goal is to make profits on the rates differential, as long as there is no adverse move on the exchange rate for the position of the trader.

The described mechanism explains why central banks reduce interest rates with the final aim to depreciate the local currency, as happened in Switzerland and Denmark.

Figure 1.9 shows the experience of Denmark: till the end of 2014, the Danish Krone (DKK) was appreciating against the Euro (declining trend of the pair EUR/DKK, highlighted by the blue arrow); the rate cuts in negative territory of January 2015 allowed the Danish central bank to spur the depreciation of the DKK, bringing the exchange rate back in the desired range.

Figure 1.9: EUR/DKK exchange rate (daily candles chart)

Source: chart from Tradingview

If we consider, instead, the case of Switzerland, the picture is different: in January 2015, the SNB announced the decision to abandon the ceiling of 1.20 Swiss Franc (CHF) per Euro, previously set to avoid excessive appreciation of the Franc. The communication has been accompanied by a 50 bps rate cut, already in negative field, with the aim to make the currency less attractive; however, the news regarding the ceiling loosening prevailed, producing a strong appreciation of the CHF towards the Euro as a short-medium term result.

Chapter 2: Monetary policy transmission mechanism

In this chapter, the general transmission mechanisms of monetary policy will be illustrated, starting from an overview of the main channels involved and focusing in particular on the peculiarities of negative interest rates. Empirical evidence regarding NIRP will be presented, analysing the results on financial markets and on bank lending activity, with a special attention to the Euro area. Moreover, the interaction of NIRP with other monetary policy tools, such as Forward Guidance and Quantitative Easing, will be considered in the analysis. Finally, the impact of NIRP on output and inflation is discussed as conclusion of the section.

2.1. Transmission channels

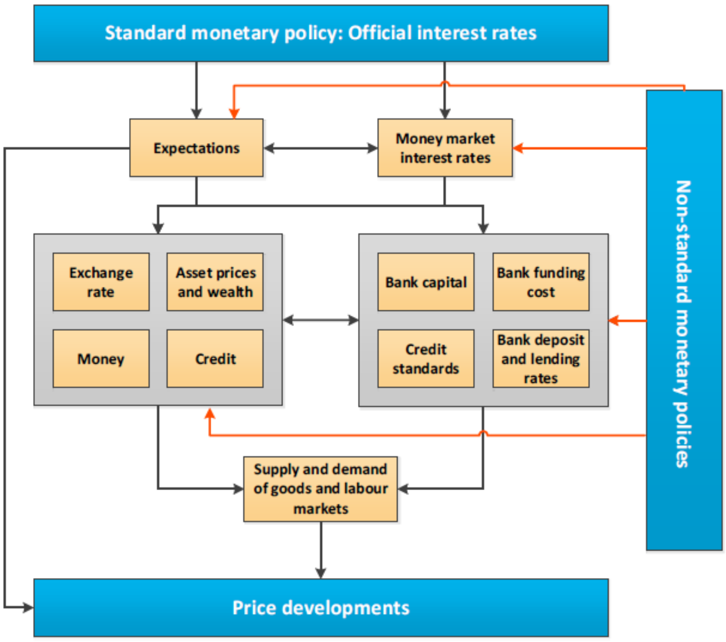
Before entering in detail into the empirical results of NIRP, it is useful to explain how monetary policy works in general. The typical transmission mechanisms of monetary policy are introduced, highlighting how NIRP is expected to behave in the overall framework.

The ECB, taken as reference in the whole paragraph, has the declared objective to maintain price stability. In Figure 2.1 it is shown the transmission mechanism of monetary policy until the last step of the chain, represented by inflation and economic activity.

The central bank steers short-term interest rates and influences expectations with the aim to reach the established final goal regarding price developments. In order to accomplish its task, the ECB manages the key interest rates[4] (the so called interest rates corridor is shown in Figure 2.2) and disposes of open market operations to manage the liquidity in the market. In addition to these standard tools, the central bank has adopted, in particular after the Great Financial Crisis, a panel of unconventional measures that complement and empower the traditional ones: among these we mention asset purchase programs, forward guidance, targeted long-term refinancing operations, NIRP and the extension of collaterals.

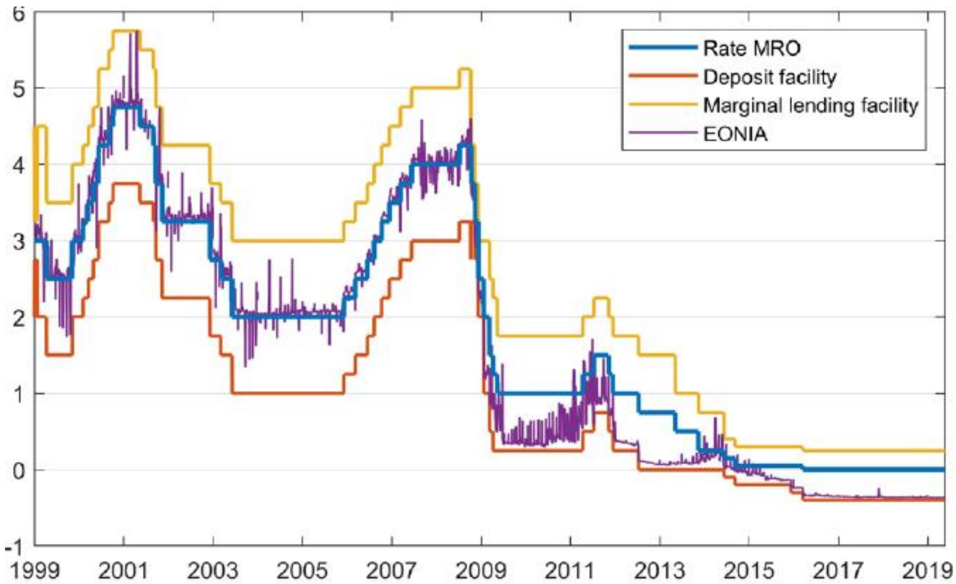
[4] The key interest rates for the Euro area are:
The interest rate on the main refinancing operations (MRO), which provide the bulk of liquidity to the banking system.
The rate on the deposit facility, which banks may use to make overnight deposits with the Eurosystem.
The rate on the marginal lending facility, which offers overnight credit to banks from the Eurosystem.
Source: ECB

Figure 2.1: Transmission mechanism of monetary policy



Source: Beyer et al. (2017)

Figure 2.2: ECB interest rates corridor



Source: ECB

In general terms, the decisions of the central bank reach the real economy passing mainly through two interrelated paths, the banking system and the financial markets. Going more in deep, it is possible to subdivide the transmission mechanism of monetary policy into several channels that contribute to the final result (the different channels are summarised in Table 2.1).

- *Interest rate channel*: the first result of a cut (or increase) in the key interest rates is on the cost of money since the decision directly affects money market rates and indirectly deposit and loan rates. Also in negative territory, the mechanism is expected to work in the same way, even if with some peculiarities. The effect on money market interest rates and on the short-term part of the yield curve can be similar to rate changes in positive field, while a further impact on longer-term rates can be generated by NIRP. The reason of this behaviour is detailed when explaining the portfolio channel. Long-term rates are particularly relevant, and so the contribution of NIRP can be specifically precious, because economic decisions such as investment or saving are actually based on long term (real) rates.

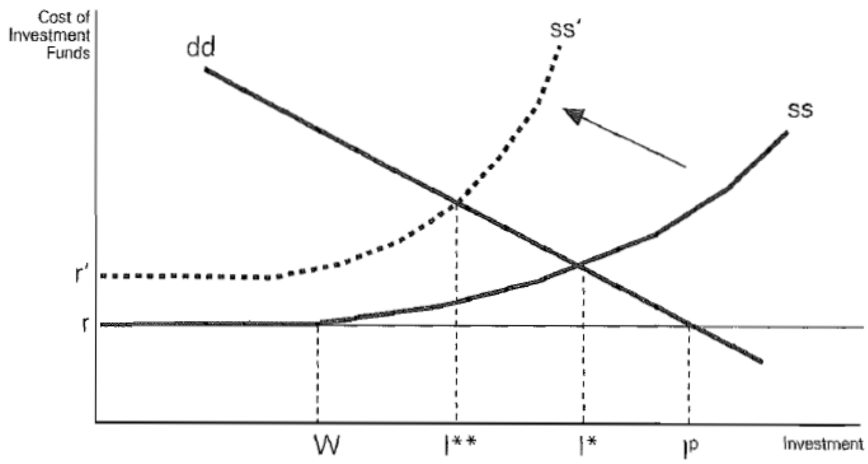
  However, NIRP presents, in principle, also another side of the coin: some impediments to the transmission mechanism may arise if, for example, banks avoid passing negative rates to depositors, being worried about the possible loss of customer base. In fact, in particular in case of retail depositors, the threat of cash hoarding in front of negative rates may be concrete. In addition, another subtle concern regards the impact of NIRP on bank's profitability and the correlated reaction of banks in the matter of pass-through to lending rates (Arteta et al., 2016).

- *Credit channel*: in addition to the cost of money, other variables contribute to the pass-through of monetary policy. These forces regarding the sphere of credit are synthetised by two well-known mechanisms, the *balance sheet channel* and the *bank lending channel*.

  Starting from the former, the reference models are Greenwald & Stiglitz (1993) and Gilchrist & Zakrajsek (1995). The basic concept is that a lower level of interest rates translates into a higher net worth because of the reduced rate used in the actualisation factor; a higher net worth means an increased value of collateral, that allows the reduction of the so called external finance premium. In fact, in presence of credit market imperfections such as asymmetric information, lenders try to alleviate the principle-agent related costs imposing a risk premium to who is asking for external funds. Here, the value of collaterals enters the game, reducing the riskiness of the borrower perceived by the lender and so also the external finance premium that the borrower has to face.

Figure 2.3 depicts the effect of a tightening monetary policy: *dd* curve represents the demand for funds, while *ss* is the supply of funds. The latter is horizontal until a level of investment equal to *W*, the net worth of the firm, then it becomes upward sloping. "*Beyond W, lenders charge a premium over the open-market rate to compensate for the increased probability of opportunistic behaviour on the part of borrowers*". This is the statement used by Gilchrist and Zakrajsek (1995) to explain that "*credit market imperfections create* a *wedge between the costs of external and internal finance*".

Figure 2.3: Effect of a rate increase on the premium for external funds



Source: Gilchrist and Zakrajsek (1995)

Following a rate increase, we have that r' > r as stressed by the interest rate channel, but also additional effects are present.

- ✓ The net worth is reduced, meaning less funds available at internal cost.
- ✓ The external finance premium increases (the ss curve becomes steeper) due to the worsened financial position of the firm (reduced net worth and possible higher interests on debt) that makes the firm appear riskier. This additional factor is what is

known with the name *financial accelerator*: here it is evident the important role of financial variables in affecting real economic decisions, enhancing the impact of a change in the interest rate. In fact, in the figure, the level of investment *I*** is affected by all these forces, comprised the acceleration effect, that contribute to worsen the cutting of investments after a rate increase.

Moving instead to the bank lending channel, the framework by Bernanke & Blinder (1988) results complementary to the traditional money view. A policy action affects not only the cost of money, and so the demand for loans, but also the supply of credit. For example, after an accommodative policy that increases the reserves of banks, these latter have more liquidity available to increase loans supply.

NIRP should further stimulate the use of excess reserves to increase lending since it imposes a kind of tax on liquidity. At the same time, it is necessary to monitor possible adverse effects of negative rates on banks' profitability and capital, that would lead banks to increase lending rates as a compensation, producing as a final result a contraction of credit generation.

- *Portfolio channel*: a policy rate cut, even in negative territory, has a direct impact on short-term rates. Then, the expectations about the future path of policy rate determine the transmission to longer-term rates. NIRP can be considered "special" in this field, for a set of reasons. The adoption of NIRP has infringed a lower bound that was considered as the extreme reachable and, as a consequence, it is also responsible of the extension of the spectrum of expectations in terms of further accommodation. This concept will be further deepened, also through empirical evidence, in the next section; however, in a nutshell, the idea is that, once removed the zero lower bound, economic agents cannot exclude additional cuts to more negative values, giving in this way more breath to expectations of further easing policies and so enhancing the effect on the longer-term part of the yield curve. The so called *expectations channel*, here taken into account, is also targeted by forward guidance, whose interaction with NIRP will be highlighted.

In addition, NIRP is able to affect long-term rates also through the *risk taking channel* and what is known as the "*search for yield*" phenomenon. The imposition of taxes on cash kept at the central bank stimulates banks to put in place a portfolio rebalancing activity, in order to compensate the additional costs. This is the search for yield, that can push to generate new and riskier loans and to invest in riskier assets and/or in assets with longer maturities, producing an increase in prices of longer-term bonds (so lower yields).

Other economic agents are also characterised by an enhanced risk taking behaviour in presence of lower short-term rates (in particular in very low or negative rates environments), resulting typically in a compression of term, liquidity and risk premia. This means that riskier asset classes such as equity may experience an appreciation as a consequence of monetary policy easing.

The outcome, as explained, is a higher level of *asset prices*, that can trigger a set of forces.

- *Confidence effects*: higher asset prices entail a more wide-spread optimism that boosts spending.
- *Wealth effects*: the increased financial wealth due to the appreciation of the detained assets stimulate consumption and so aggregate demand.
- *Cost of capital channel*: in addition to the reduced cost of debt due to lower rates, firms see an advantage in collecting capital and investing when stock valuations are high.
- *Balance sheet effects*: the increased financial wealth translates into higher collateral value that enables the balance sheet mechanism described above.
- *Additional risk taking*: the boosted asset values may lead banks and other financial actors to accept higher risks while still respecting capital requirements, given the improved balance sheet situation they see. This means that the increase of asset prices, partially generated by an enhanced risk taking behaviour, may stimulate further risk taking in a vicious spiral. The danger of risk mispricing and asset valuation distortion is, in fact, one of the key variables monitored to preserve financial stability, in particular in presence of very low or negative rates for prolonged periods of time.

- *Exchange rate channel*: as anticipated talking about the cases of Denmark and Switzerland, rate cuts can be exploited to promote export, making the local currency less attractive and so producing a currency depreciation. This last encourages international purchases from who enjoys an increased purchasing power due to exchange rate effects. NIRP, extending the range of possible accommodative rate cuts, allows central banks to influence exchange rates even in an environment characterised by already ultra-low interest rates.

The different channels just analysed are synthetised in the table below, by Beyer et al. (2017).

Table 2.1: Monetary policy transmission channels

Transmission Channels	Description
Interest rate	Policy measures have an impact on money market rates, bank funding costs and saving and borrowing costs
Money	Changes in money supply affect liquidity conditions in the economy which may affect spending
Exchange rate	Affects price of imports and competitiveness
Asset price and wealth	Asset prices react to policy changes with implications for wealth due to valuation effects
Balance sheet and profitability	Changes in policy affect private sector balance sheets, net worth and collateral value
Bank funding and lending	Changes in policy affect bank lending supply and demand
Bank capital	Changes in policy have implications for bank capital and profitability
Risk-taking	Search for yield and lending behaviour. Accommodative policy for too long a period can create incentives for more risk-taking
Expectations	Influence private sector long-term expectations including by signalling the future policy course

Source: Beyer et al. (2017)

2.2. Empirical evidence: financial markets channel

In this paragraph and in the following one, the previously exposed theoretical considerations about NIRP are tested, collecting the main empirical results about this quite recent monetary policy tool. Actually, exactly this novelty of NIRP as part of the panel of policy instruments is one of the main difficulties for empirical research: the limited experience and the few data available about actions in negative territory reduce in fact the power and the robustness of econometrics and quantitative approaches. Moreover, the coexistence and the interaction with other tools makes the identification and isolation of specific impacts of NIRP more challenging. This is particularly true in case of studies that target the direct measurement of aggregate effects, while other approaches based on high-frequency identification and micro-data have instead the drawback to provide only indirect evidence of macroeconomics results (IMF, 2021).

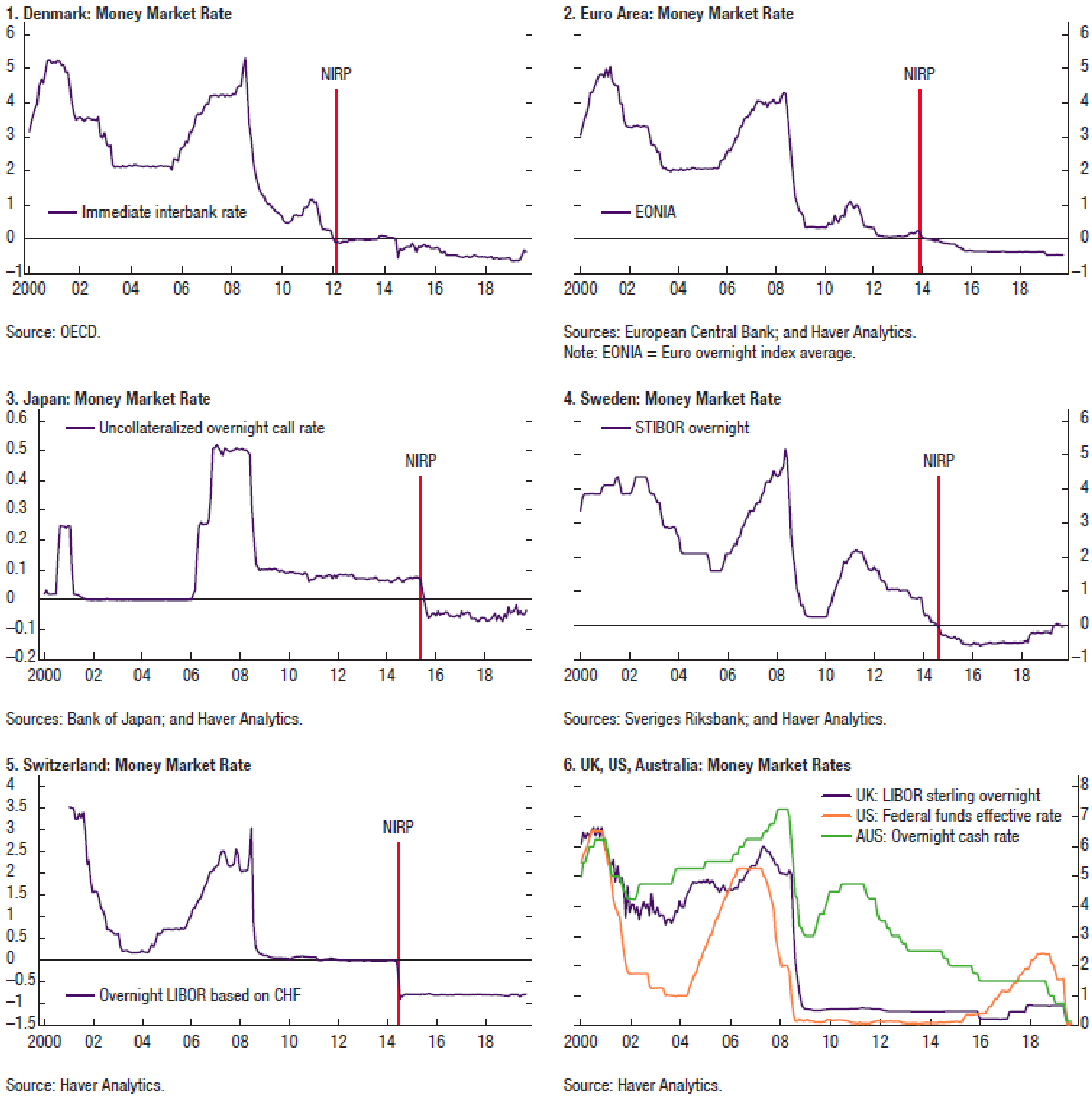
Taking into account the challenges mentioned above, the results about the implementation of NIRP will be proposed through a mix of visual inspection (e.g. charts of financial assets reactions to NIRP), qualitative and quantitative considerations, and also econometrics applications adopted in the literature (see for example Arteta et al., 2016, Rostagno et al., 2019, Bräuning and Wu, 2017).

The analysis starts from a detailed overview of the effects of negative interest rates on the financial markets, keeping in mind the following mechanism: changes in policy rates are reflected first of all in short term rates, starting typically from the money market, and from there they can be transmitted to the entire yield curve. Then, since the term structure of risk-free rates represents a benchmark to price riskier securities, also asset classes such as corporate bonds and stocks are affected by the monetary policy action (IMF, 2021).

2.2.1. Money Market Rates

The most immediate impact of policy rates changes is reasonably on short-term money market rates, and this seems true also in case of NIRP. As explained talking about the interest rate channel, the transmission mechanism to short-term rates is not expected to vary when moving in negative field. The evidence collected so far supports this statement: as it can be seen in Figure 2.4, in countries adopting NIRP (such as Denmark, Japan, Sweden, Switzerland and the Euro area considered as a whole) short term money market rates have followed policy rates when the latter moved below zero. We notice, instead, that in the US and in the UK, which did not experience NIRP, money market rates are above the ZLB, as expected.

Figure 2.4: Short term money market rates and NIRP

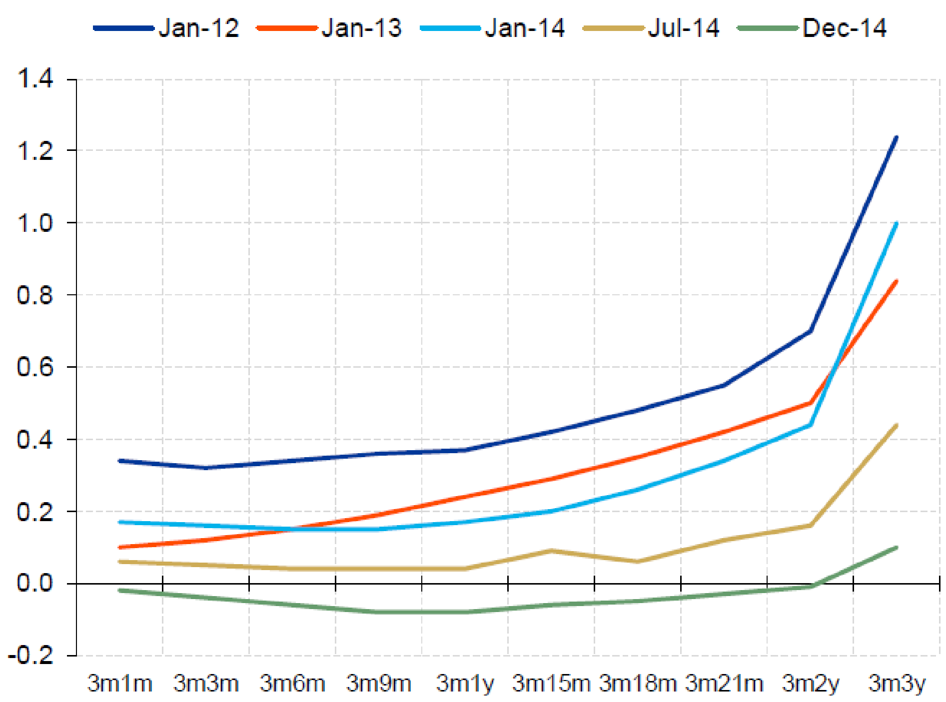


Source: IMF (2021)

In the figure above, the focus is on overnight rates (such as the €STR, formerly EONIA for the Euro area), the shortest maturity that can be considered. However, as highlighted by Bech and Malkhozov (2016), also other money market rates became negative following policy rates cuts below zero. For example, we can notice that, from 2016, the EURIBOR is negative over its entire spectrum, until the maturity of 12 months, testifying the complete pass-through of NIRP to the money market.

The transmission to not immediate money market rates suggests that economic agents started to to consider NIRP as something not merely transitory but as a phenomenon with a certain persistency. This idea is corroborated by Schnabel (2020), who shows that after the DFR became negative, almost the entire 3-months EURIBOR forward curve shifted down till negative rates (see in Figure 2.5 the evolution of the curve in July and December 2014, after the rate cuts in negative territory of June and September).

Figure 2.5: Evolution of 3-months Euribor forward curve after NIRP

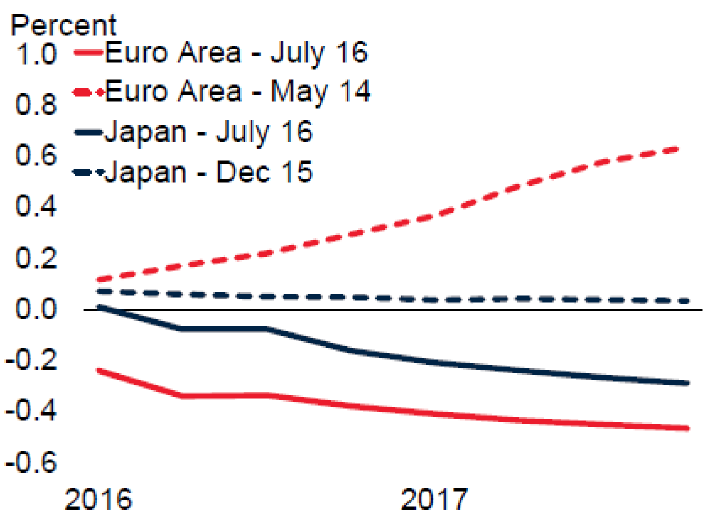


Source: Schnabel (2020)

The forward curve taken into consideration represents the expected 3-months Euribor at certain future dates (e.g. 3m 1y means the 3-months Euribor expected on the market looking 1 year ahead). For this reason, the curve can be interpreted as a baseline projection of future interest rates and the event pointed out by Schnabel (2020) is therefore an important evidence of the perceived persistency of negative rates and of the expectations about the future path of policy rates, once removed the zero lower bound.

The transformation of expectations about policy rates, one of the main merits of NIRP, is pointed out also in Figure 2.6, in which Arteta et al. (2016) stress how expectations changed in Japan and, even more, in the Euro area, after the introduction of negative policy rates[5]. It is definitely clear that agents considered quite persistent the new situation and besides they did not exclude further easing interventions.

Figure 2.6: Policy rate expectations before and after NIRP



Source: Arteta et al. (2016)

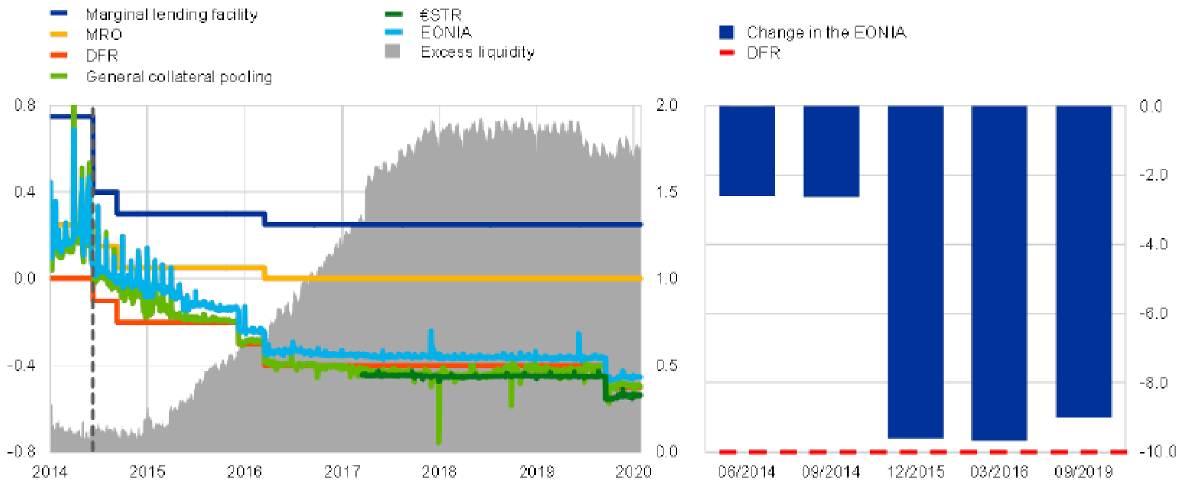
[5] Negative policy rates have been introduced in January 2016 in Japan, while several cuts in negative territory characterised the Euro area (June and September 2014, December 2015 and March 2016) before July 2016, the date considered by Arteta et al. (2016).

To deepen the discussion regarding the pass-through, Eisenschmidt and Smets (2019) provide interesting considerations and additional details about the transmission dynamics. They underline that the excess liquidity in the system has played a relevant role in favouring the pass-through to money market rates. This is conceptually robust given that banks found themselves with large reserves of cash and had to decide how to manage it; once the deposit facility rate is cut, to the extent of becoming a tax charged to commercial banks, it is quite straightforward that the latter consider alternative uses of cash, like in the interbank market. Indeed, we have previously discussed that the holding of physical cash entails not negligible costs, that make the interbank market appetible even with negative rates. As a natural consequence of the increased supply in the money market, rates have decreased to negative values.

However, it is also interesting to notice that the described mechanism has not been immediate. Eisenschmidt and Smets (2019) show that, in the Euro area, the process completed only in May 2015. In the initial months after the 2014 DFR cuts in negative territory, the EONIA did not followed that policy rate so closely (in Figure 2.7, Left panel, the EONIA does not track closely the DFR until half 2015) and reacted only smoothly to policy changes (in Figure 2.7, Right panel, it is shown that the EONIA had a weak reaction to DFR cuts in June and September 2014). The authors attribute this lagging to the need of time for market participants to adequate to the "new world": nominal negative rates were something quite revolutionary and they required also technical and practical adjustments to IT systems and legal documentation among other changes. In addition, Boucinha et al. (2020) stressed the role of excess liquidity also as an explanation of the delay in the transmission of the initial DFR cuts. In fact, it is just when the excess liquidity increases consistently that the EONIA (or €STR) tracks closely the DFR, otherwise the MRO rate is the benchmark: the authors explain that, when the supply of reserves has massively grown due to asset purchase programs, banks found themselves with huge amounts of excess liquidity (in grey in Figure 2.7, Left panel) and started to price the cost of overnight funding (EONIA) very closely to the DFR. On the contrary, when the reserves are sufficient just to match the demand (due to reserve requirements) in the banking system, commerical banks have the market power to charge overnight rates closer to the MRO.

Figure 2.7: Short term money market rates and excess liquidity

(left panel: left-hand scale: percentages; right-hand scale: EUR trillions; right panel: basis points)



Notes. The right panel shows the change in the EONIA on the first day after each rate cut relative to the average EONIA in the five business days before each rate cut. The pre-€STR is used before October 2019. In the left panel, the vertical broken line indicates the introduction of the negative DFR. In the right panel, the horizontal broken line indicates the size of each of the cuts in the DFR (10 basis points). Latest observations: 27 January 2020.

Source: Boucinha & Burlon (2020)

The observations presented until now testify for sure a material impact of NIRP on the money market. Boucinha & Burlon (2020) have measured the immediate reaction of EONIA to DFR cuts (Figure 2.7, Right panel), but it can be interesting to deepen the analysis on money market rates resorting also to other econometric applications in the literature. In particular, Arteta et al. (2016) and Bräuning & Wu (2017) adopt different approaches based on high-frequency identification, with the aim to quantify the specific contribution of NIRP, trying to decouple other factors and different dynamics that may play a role in determining the level of money market rates. The two methodologies are presented in the following and both the studies will be referred to also in the next paragraphs since they cover a quite comprehensive set of financial variables.

Arteta et al. (2016) employ the event study methodology over short time windows (i.e. the announcement day) in order to quantify the impact of monetary policy announcements.

The approach allows to detach the effects of policy changes from other unrelated determinants influencing the financial assets taken into consideration; however, the study is affected by relevant limitations, some of them already mentioned among the general problems faced by empirical research on NIRP. The scarce dimension of the sample (17 observations across countries that experienced rate cuts in or into negative territory) reduces the statistical robustness of the econometric approach. The concurrent announcement of other unconventional policies (see Annex, Table A1, column "Complementary policies announced" for more details) such as QE and forward guidance, undermines the isolation of NIRP results, in particular as concerns the impact on longer-term rates. The anticipation effects due to already matured expectations are not captured measuring changes just on the announcement day.

Once clarified these issues, it is interesting to notice that, considering a one day time window around the announcement, money market rates (1-month and 3-months interbank market rates) dropped on average by 2 to 3 basis points. The term "on average" should actually be taken with caution here because of another severe caveat in the methodology by Arteta et al. (2016), the fact that rate cuts of different sizes are equally weighted in the average. The relevance of this limitation results particularly evident if we dig deeper, looking at country-specific changes: for example, the 0.5% rate cut by the Swiss National Bank in January 2015 (much larger than the 0.1% change typically adopted by the ECB) has produced huge variations in the interbank rates, affecting in this way the overall average in a decisive way.

Focusing on the Euro area, the average response of money market rates has been quite moderate, around -0.6 bps, maybe reflecting already anticipated expansionary expectations. The behaviour is consistent with the reactions to conventional rate cuts, even though the magnitude of changes is significantly weaker on average. For the sake of completeness, it is necessary to stress how important differences make the two samples (NIRP period vs conventional rate cuts from year 2000) hardly comparable: the main refinancing operations (MRO) rate has been subject to much larger changes in combination with standard DFR cuts rather than during NIRP era, and monetary policy decisions had much stronger effects on financial markets during the 2008 and 2011 crisis, when the volatility was at very high levels.

Bräuning & Wu (2017) adopt a different and more refined approach, that is based even in this case on high frequency identification but it exploits a factor model estimated from asset prices[6] changes around monetary policy announcements (78 ECB's announcements from July 1, 2009 to June 2, 2016). This methodology, compared to the one by Arteta et al. (2016), allows an improvement in terms of isolation of the effects due to a given monetary policy tool. In fact, through a principal component analysis (PCA) and proper adjustments, the factor model identifies three well separated terms of monetary policy shocks: "*changes in the target rate, forward guidance about the future path of the target rate, and policies that affect longer-term interest rates through large-scale asset purchases or long-term lending programs*". In practice, asset prices variations following each announcement are explained by the combination of the three factors, in a way that makes possible to deconstruct the relative contribution of each monetary policy tool.

Once identified the shocks related to the three dimensions mentioned above, the authors regress changes in asset prices as shown below.

$$\Delta y_t = \begin{cases} \alpha_{\text{pre-NIRP}} + \beta_{\text{pre-NIRP}} \cdot F_t + \epsilon_t, & \text{if meeting during pre-NIRP period} \\ \alpha_{\text{NIRP}} + \beta_{\text{NIRP}} \cdot F_t + \epsilon_t, & \text{if meeting during NIRP period,} \end{cases}$$

where Δy_t represents the changes in the response variable on the announcement days, t is an index representing the dates of ECB meetings, F_t is a 3x1 vector that collects the identified shocks (surprise changes) and ε_t is a zero mean error term. It is interesting to notice that the observations sample has been partitioned in order to compare the reactions to shocks during pre-NIRP and NIRP periods and, for this purpose, the slope β (and the intercept α) of the model are allowed to differ across the two regimes. The authors scale the monetary policy shocks so that their variance is unitary and an increase (decrease) corresponds to a tightening (accommodative) action. In this way the β coefficients can be interpreted as reactions to a one standard deviation change in the shocks.

[6] The assets considered are the current EONIA swap rate, the 1-month forward EONIA swap rate, the third and fourth Euro Interbank Offered Rate (EURIBOR) futures and the 2-, 5-, 10-year generic euro area government bond yields (risk-free German bond yields)

Focusing on the responses of interbank rates to the target rate factor, we can observe interesting results. As you can see looking at Table 2.2, a decrease in the policy rate always reduced interbank rates on average between 1.3 and 1.8 bps per one standard deviation change. This happened over all maturities until 12 months and in a comparable way during the two regimes, to the extent that the p-values confirm with a high level of confidence the similarity of the βs among the different periods. These findings are in line with the visual explorations that suggest a robust pass-through of negative rates to the money market and with the assumption of a similar transmission mechanism to short term rates before and during NIRP.

Table 2.2: Effects of monetary policy shocks on interbank market rates

	1-Month Rate (1)	3-Month Rate (2)	6-Month Rate (3)	12-Month Rate (4)
Effect of Target Surprise				
Pre-NIRP Period	1.480***	1.323***	1.373***	1.586***
	(3.38)	(3.47)	(3.87)	(4.24)
NIRP Period	1.515***	1.711***	1.798***	1.844***
	(5.62)	(7.01)	(7.51)	(10.57)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.946	0.393	0.320	0.531
Effect of Path Surprise				
Pre-NIRP Period	0.227	0.123	0.031	-0.166
	(0.69)	(0.33)	(0.08)	(-0.29)
NIRP Period	-0.100	0.059	0.189**	0.275***
	(-1.30)	(0.67)	(2.39)	(4.24)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.335	0.868	0.711	0.445
Effect of Term Surprise				
Pre-NIRP Period	-0.170	0.168	0.479	1.003**
	(-0.62)	(0.55)	(1.47)	(2.25)
NIRP Period	0.200	0.472**	0.612***	0.859***
	(0.76)	(2.09)	(3.23)	(6.03)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.331	0.425	0.725	0.758
Observations	78	78	78	78
R-squared	0.512	0.534	0.588	0.631

Notes. This table shows the estimated coefficients from regressions where the dependent variables are the changes of EURIBOR interbank lending rates at various maturities on the ECB announcements between July 2009 and June 2016. The independent variables are the identified surprise changes in the three monetary policy dimensions, scaled such that an increase corresponds to a monetary policy tightening. The "NIRP Period" starts on June 11, 2014, when the ECB introduced the negative deposit facility interest rate; the "pre-NIRP Period" denotes the period prior to June 11, 2014. Coefficients are in units of basis points per standard deviation change of the monetary policy surprise. T-statistics based on HAC-consistent standard errors are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

Source: Bräuning and Wu (2017)

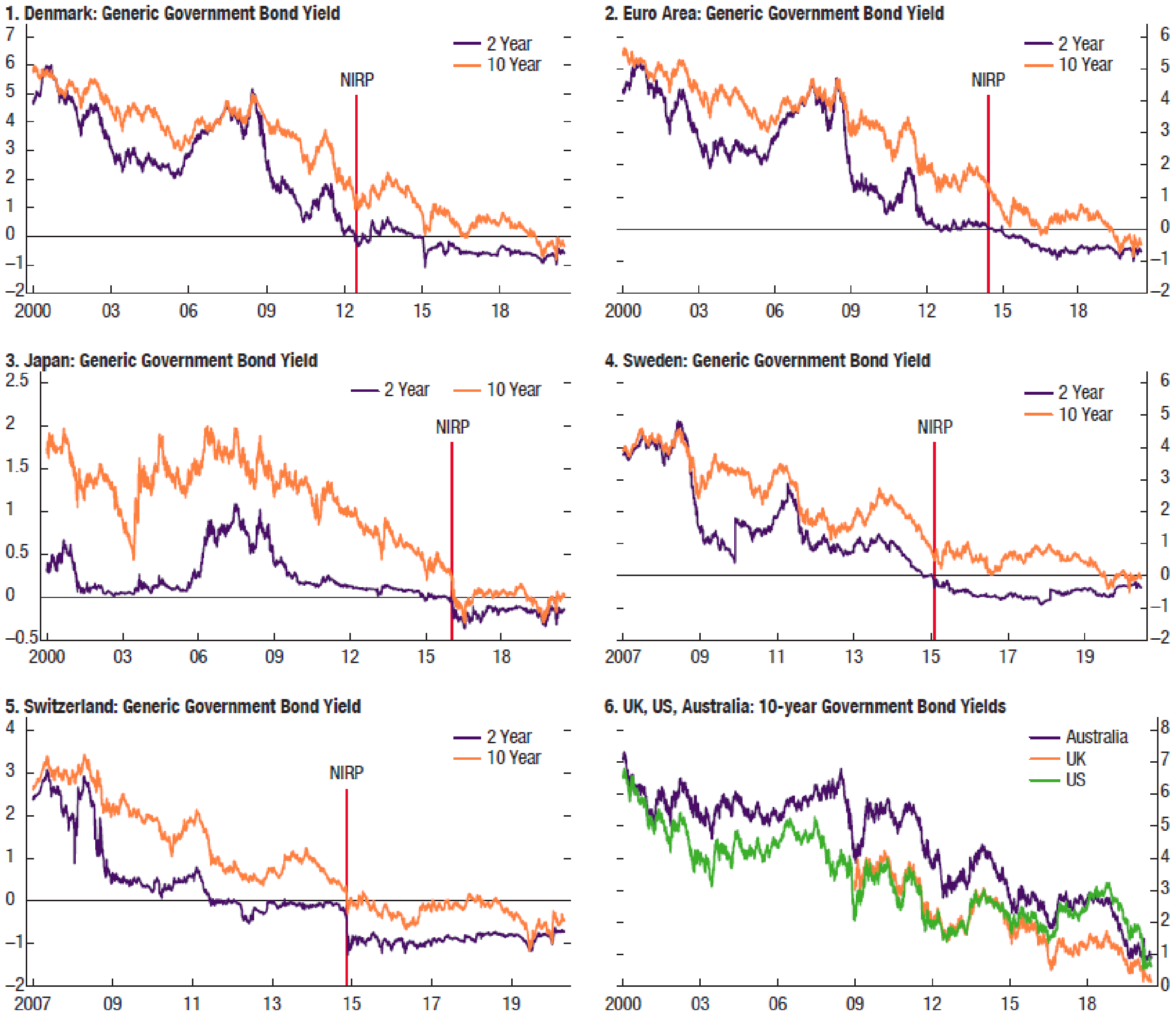
2.2.2. Yield Curves

After having discussed the effective transmission of monetary policy changes to short-term money market rates, the next step of the analysis focuses on the entire yield curves of risk-free rates and government bonds. As previously anticipated (paragraph 2.1, "portfolio channel"), we expect a significant impact of NIRP also on medium-long term rates, thanks to its peculiarities compared to conventional rate cuts:

- NIRP removes the non-negativity constraint on current and future short-term rates. Expectations are revised, including even more accommodative scenarios, and these propagate throughout the yield curve. Grisse et al. (2017) have proven empirically that, when a rate cut in negative territory lowers the perceived location of the lower bound, the impact of the monetary policy decision on financial markets is enhanced.
- Negative rates stimulate investors demand for longer-term assets in a more pronounced way, thus exerting a stronger downward pressure on term premiums. In fact, the charge imposed on excess liquidity and the propagation of negative rates to short-term assets lead naturally to an increased appetite for longer-dated (and/or riskier) assets, in search for yield. The effect is particularly enhanced in case of negative rates because some economic actors, such as certain categories of institutional investors, have an absolute aversion for negative nominal yields, due to their commitment to return positive performance to their clients.

The first step of our analysis is the visual and qualitative inspection of the behaviour of the yield curves following NIRP. The empirical evidence shows that the entire spectrum of the yield curves has shifted downward after NIRP announcements, with negative rates that spread to government bonds yields also at longer maturities. In Figure 2.8, for example, we can notice that both government bonds with 2 years maturity and longer dated ones (10Y maturity) started to exhibit negative yields in countries adopting NIRP (Denmark, Japan, Sweden, Switzerland and the Euro area). This, instead, has not happened in no-NIRP countries (UK, US), even though also in those cases bond yields are characterised by a declining trend.

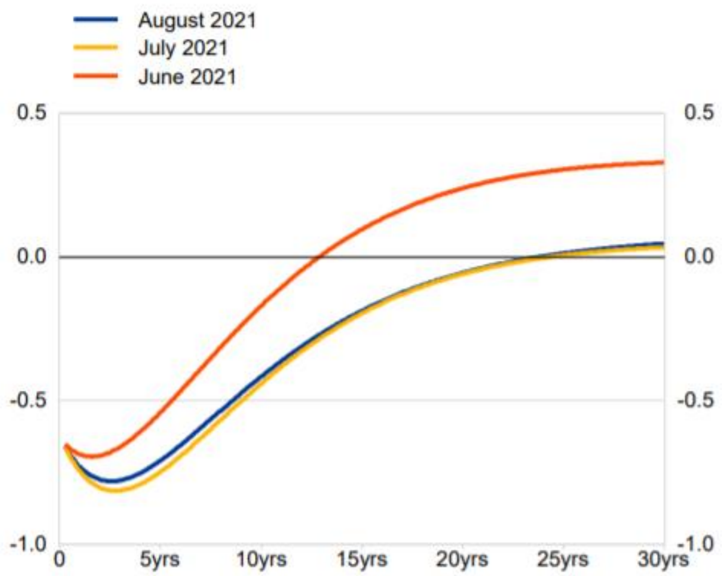
Figure 2.8: Government bond yields and NIRP



Source: IMF (2021)

Looking at the current situation in the Euro area, a large portion of the yield curve, based on AAA-rated government bonds, lies at negative values (see, in particular, the yellow and blue curves in Figure 2.9).

Figure 2.9: Euro area spot yield curve



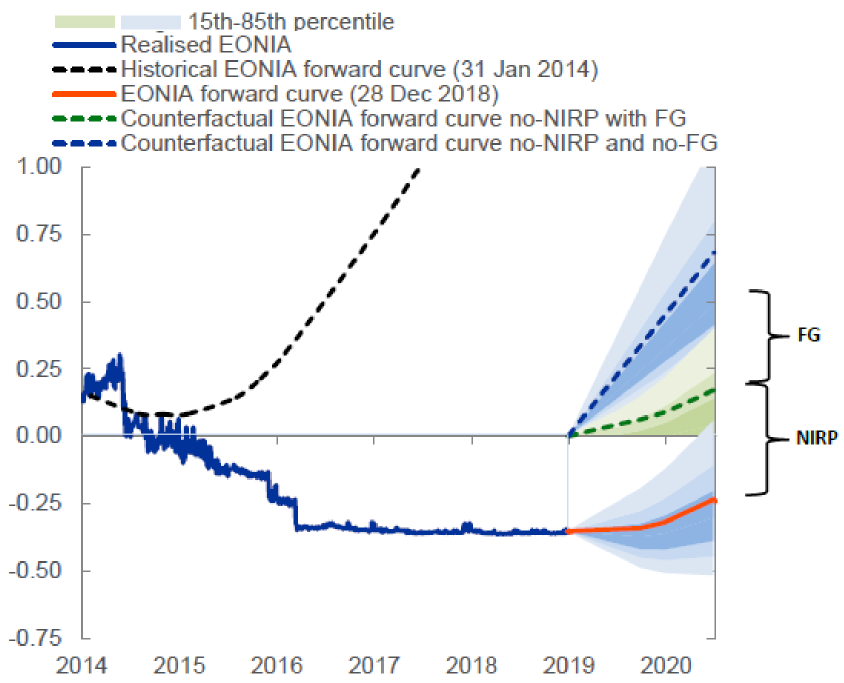
Source: ECB Statistical Data Warehouse

The above considerations testify that the pass-through of negative rates has been relevant also for medium-long term maturities. However, it is fundamental to notice that a handful of forces, both structural and of monetary policy, have contributed to shape this outcome. As a result, to deepen our analysis, it is interesting to investigate the specific impact of NIRP on the yield curve, trying also to decouple the effects of other unconventional monetary policies. In fact, forward guidance and asset purchase programs have as well long-term rates as their target and, as we will see, the different measures complement and reinforce each other.

The first approach we present in order to assess the individual contribution of NIRP is the one by Rostagno et al. (2019), reproposed also by Boucinha & Burlon (2020).

The methodology used is a counterfactual analysis that assumes a no-NIRP scenario with current and expected future short-term rates that cannot go below zero. In fact, without the adoption of NIRP, the zero lower bound represents an uncrossable limit for expectations and, in practice, this translates in counterfactual rate distributions in which the probability mass that markets assigned to negative rates is re-allocated to the ZLB. The altered distribution of expectations reflects in the counterfactual EONIA forward curve (see the dashed green line in Figure 2.10). It is evident and expected that the curve generated in this way lies at higher rates compared to the actual (in presence of NIRP) EONIA forward curve as of December 2018 (depicted in red). Rostagno et al. (2019) display (in dashed blue) also the result of a no-NIRP counterfactual with the additional assumption of having neither forward guidance. This second counterfactual curve is above the first one because it suffers also from the absence of forward guidance, that we know it can have an accommodative effect on expectations.

Figure 2.10: Expectations of future short term rates: observed and counterfactual



Source: Rostagno et al. (2019)

Once derived the counterfactual EONIA forward curve, the resulting rates are used in a large Bayesian Vector Autoregression (BVAR) to assess the specific impact of NIRP on the yield curve and on a selection of financial and macroeconomic variables[7]. This step of the methodology is described below, starting from its formal representation.

$$u_{t+h} = E\left(y_{1t+h} \mid \Omega_t, z^*_{t,\ldots t+h}\right) - E\left(y_{1t+h} \mid \Omega_t, z_{t,\ldots t+h}\right)$$

The idea is to evaluate the impact of a policy tool (NIRP in our case) on a set of variables, through the comparison of a policy scenario (first term on the right-hand side) and a no-policy one (second term on the right-hand side). Ω_t is the state of the economy at time t, u_{t+h} measures the change in the selected variables y_1 (e.g. inflation and GDP) comparing the two scenarios, $z_{t\ldots t+t+h}$ are the policy related variables from time t to t+h in case of no-policy scenario, while $z^*_{t\ldots t+h}$ are the same variables in the policy scenario.

In particular, in case of NIRP, the variables z affected by the policy are the EONIA and the 3-month EONIA forward in 12 and 18 months. The values of these current and forward rates differ from z to z* according to the results obtained before in the counterfactual forward curve.

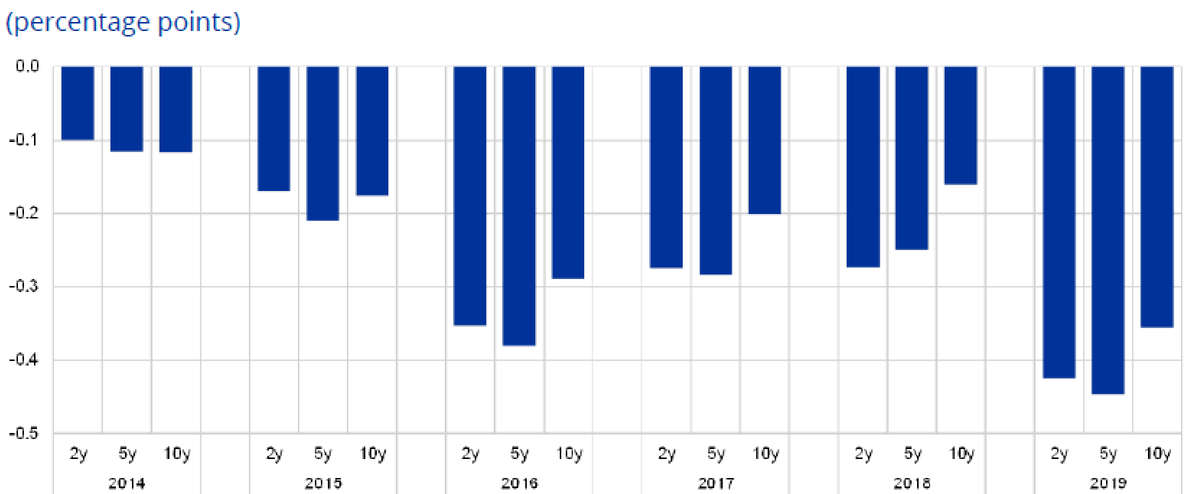
The coefficients of the VAR are estimated using real-world data and then the model is applied to assess how variables such as GDP and inflation would have changed in the counterfactual no-NIRP scenario (feeding the values $z_{t\ldots t+t+h}$ from the counterfactual forward curve obtained above). The difference in the value of GDP and inflation (but also other variables of interest) between the policy scenario and the no-policy one represents the estimated individual contribution of NIRP.

[7] The model includes 14 variables: real GDP, HICP inflation, loans to non-financial corporations, loans to households, the EONIA, the 3-month EONIA forward in 12 and 18 months, the 2- 5- and 10-year euro area sovereign yields, the lending rate on loans to non-financial corporations and households, and the interest rate rates applied to deposits of non-financial corporations and households. (Rostagno et al., 2019)

The approach described above has been used to identify the impact of NIRP also[8] on government bonds, the variable of interest in this section. Specifically, the 2-, 5- and 10-year euro area sovereign yields are the object of the analysis.

Looking at Figure 2.11, it is interesting to notice how the effects of NIRP have been quite persistent across maturities. In the theoretical discussion, we argued that NIRP is expected to have an impact on longer-term rates that is stronger if compared to those of conventional rate cuts. Here we want to check for empirical evidence for this point. In particular, in Figure 2.12, you find the different reaction across maturities of sovereign yields in case of conventional rate cuts and NIRP. The impact of standard cuts (left panel, Figure 2.12) is monotonically declining as the maturity increases, while with policy rates in negative territory the effect (right panel, Figure 2.12) is strong and persistent also on longer maturities, with a one-to-one transmission of policy rate cuts.

Figure 2.11: Estimated impact of NIRP on the sovereign yield curve

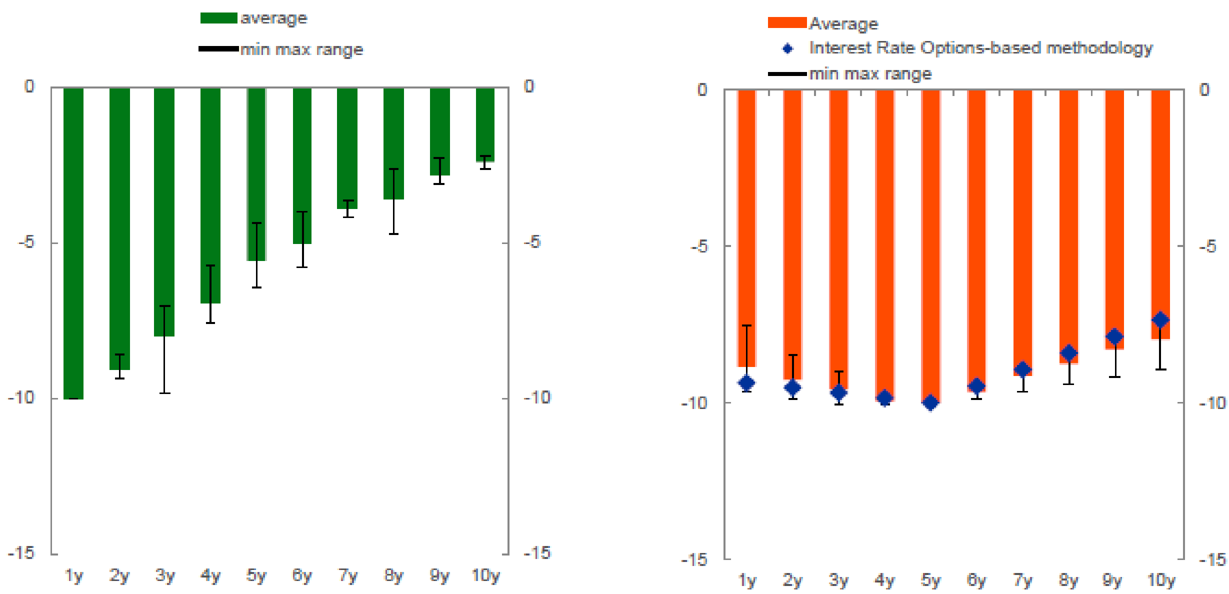


Note: The chart illustrates the impact of NIRP on sovereign yields (weighted average of German, French, Italian and Spanish sovereign bond yields), which works primarily via the short-term rate and the OIS forward curve.

Source: Boucinha & Burlon (2020)

[8] The effects on inflation and output will be object of the discussion in paragraph 2.5.

Figure 2.12: Impact of a 10 bps rate cut on sovereign yields: positive and negative territory



Note. The y axis are expressed in bps.

Source: Rostagno et al. (2019)

These results are corroborated also by high frequency studies. Arteta et al. (2016) point out that, on average, 2-year sovereign yields declined approximately by 6 basis points and 10-year yields by nearly 4 basis points during the announcement days, confirming a relevant pass-through across maturities.

Bräuning & Wu (2017), in line with the evidence in Figure 2.12, provide interesting details about the different transmission throughout the yield curve during NIRP and pre-NIRP. As expected, a target rate easing in the NIRP era is more impactful on medium term maturities[9] compared to pre-NIRP and, looking at the t-test, the result is statistically significant (see the "effect of target surprise" in Table 2.3). For example, as for the 5Y maturity, the reaction to one standard deviation policy rate change is almost doubled in terms of bps between the two regimes and the very low p-value (0.003) confirms that the behaviour pre and during NIRP is not comparable.

[9] Given the contemporaneous announcement of policy rate cuts and asset purchase programs, the effect on long-term maturities (10Y) is likely absorbed by the term factor, as explained in paragraph 2.4.

The phenomenon is observable also from a graphical point of view in Figure 2.13: before NIRP, the response to the target factor was downward sloping as the maturity increases, while in the following period the curve becomes hump-shaped, testifying a stronger impact on medium term maturities.

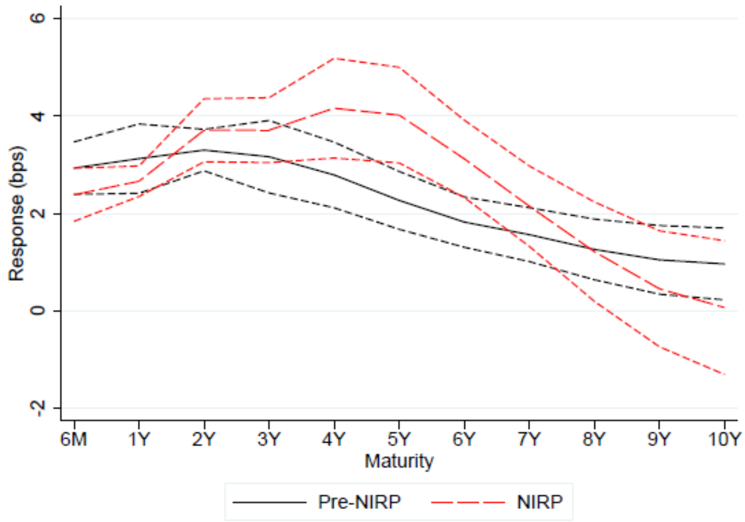
Table 2.3: Effects of monetary policy shocks on Euro-area government bond yields

	6-Month Yield (1)	2-Year Yield (2)	5-Year Yield (3)	10-Year Yield (4)
Effect of Target Surprise				
Pre-NIRP Period	2.931***	3.300***	2.268***	0.965**
	(10.70)	(15.20)	(7.50)	(2.57)
NIRP Period	2.383***	3.706***	4.017***	0.070
	(8.57)	(11.23)	(8.03)	(0.10)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.160	0.303	0.003	0.269
Effect of Path Surprise				
Pre-NIRP Period	1.005*	1.647***	1.348***	1.367***
	(1.87)	(5.48)	(3.28)	(3.07)
NIRP Period	0.658***	1.365***	1.497***	1.464***
	(11.68)	(13.14)	(7.07)	(9.55)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.520	0.376	0.747	0.837
Effect of Term Surprise				
Pre-NIRP Period	1.483***	4.799***	6.045***	4.682***
	(3.69)	(19.06)	(16.90)	(11.30)
NIRP Period	1.354***	3.436***	6.079***	7.928***
	(10.85)	(8.72)	(16.34)	(10.13)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.758	0.004	0.949	0.000
Observations	78	78	78	78
R-squared	0.815	0.953	0.936	0.858

Notes. This table shows the estimated coefficients from regressions where the dependent variables are the changes of generic euro-area government bond yields at various maturities on the ECB announcement days between July 2009 and June 2016 (generic euro-area bonds closely resemble risk-free German bonds). The independent variables are the identified surprise changes in the three monetary policy dimensions, scaled such that an increase corresponds to a monetary policy tightening. The "NIRP Period" starts on June 11, 2014, when the ECB introduced the negative DFR; the "pre-NIRP Period" denotes the period prior to June 11, 2014. Coefficients are in units of basis points per standard deviation change of the monetary policy surprise. T-statistics based on HAC-consistent standard errors are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

Source: Bräuning & Wu (2017)

Figure 2.13: Government bond yields responses to target rate shocks



Source: Bräuning & Wu (2017)

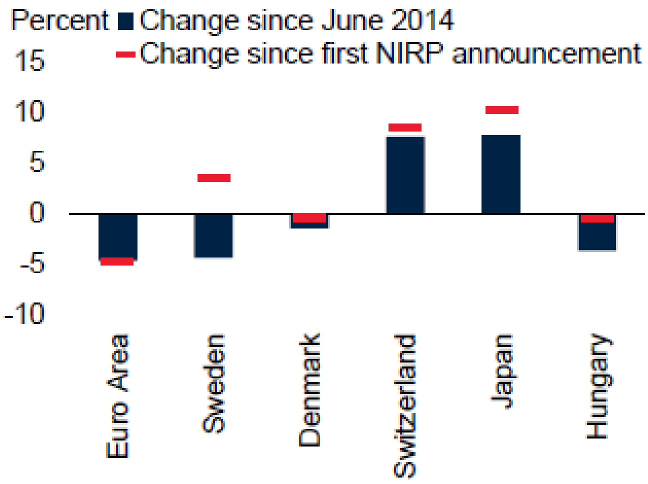
2.2.3. Exchange Rates

The exchange rate channel has been identified as a piece of the transmission mechanism puzzle, for this reason it is interesting to further study how foreign exchange market dynamics change following the introduction of NIRP. We have already reported that the Danish National Bank has adopted rate cuts in negative territory to successfully depreciate the local Krone. However, looking at the medium term, the impact of NIRP on exchange rates[10] is not always clear and has been quite different depending on the country (i.e. the local currency) considered (see Figure 2.14). Arteta et al. (2016) argue that the evolution of exchange rates is affected by the interplay of several domestic and international forces that make difficult to extrapolate the individual effect of NIRP in the medium long term. A confirmation comes from Lane (2019) that, focusing on the Euro – US Dollar exchange rate, reports how only a quarter of the rate fluctuations can be reconducted to ECB monetary policy stances. Looking in detail at Figure 2.14, we notice that Switzerland and Japan are somehow outliers, since their currencies quite strongly appreciate after NIRP. The reason of this behaviour is exactly what

[10] The variable considered, the nominal effective exchange rate (NEER), represents the amount of foreign currency (intended as a weighted average of a basket of foreign currencies) purchased with domestic currency.

explained above, i.e. the overlapping of different forces that can hide the contribution of NIRP. For example, in case of Japan, fundamental factors such as flight to safety behaviours may have dominated above NIRP effects, leading to an appreciation of the Japanese Yen. As regards Switzerland, we have already mentioned the relevance of the Swiss national bank decision to abandon the previously set ceiling rate.

Figure 2.14: Nominal effective exchange rates following NIRP



Source: Arteta et al. (2016)

However, to alleviate this identification issue, high frequency studies may be helpful to isolate the short-term contribution of NIRP on exchange rates. Bräuning & Wu (2017), indeed, found that easing target rate shocks in the Euro area induce a depreciation of the Euro, which is typically stronger than in the pre-NIRP period. Looking at the "effect of target surprise" in Table 2.4, this observation appears true in case of the US Dollar, the Japanese Yen and the British Sterling, while the effect is uncertain for the exchange rate involving the Euro vs the Swiss Franc[11].

[11] The sample used by Bräuning & Wu (2017) covers the period between July 2009 and June 2016. Since NIRP has been introduced in June 2014 and the Swiss National Bank pegged the Franc to the Euro until January 2015, a relevant part of the NIRP sample has been affected by the minimum threshold of 1.20 Franc per Euro. This limit likely undermined the effectiveness of ECB policy shocks in depreciating the Euro towards the Franc.

Table 2.4: Effects of monetary policy shocks on FX rates

VARIABLES	USD/EUR (1)	JPY/EUR (2)	GBP/EUR (3)	CHF/EUR (4)
Effect of Target Surprise				
Pre-NIRP Period	0.218***	0.087	0.170***	0.247***
	(4.12)	(0.58)	(3.26)	(3.24)
NIRP Period	0.664***	0.549***	0.376***	-0.002
	(3.28)	(4.25)	(3.95)	(-0.02)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.033	0.019	0.059	0.021
Effect of Path Surprise				
Pre-NIRP Period	0.385***	0.357*	0.151*	0.140
	(4.15)	(1.67)	(1.73)	(1.35)
NIRP Period	0.246***	0.103	0.150***	-0.010
	(4.37)	(1.49)	(4.05)	(-0.58)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.199	0.258	0.988	0.152
Effect of Term Surprise				
Pre-NIRP Period	0.531***	0.752***	0.349***	0.295***
	(6.85)	(4.57)	(5.97)	(4.62)
NIRP Period	1.124***	1.051***	0.834***	0.456***
	(8.73)	(8.41)	(7.59)	(5.40)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.000	0.147	0.000	0.130
Observations	78	78	78	78
R-squared	0.667	0.409	0.605	0.519

Notes. This table shows the estimated coefficients from regressions where the dependent variables are the (log) changes in exchange rates on the ECB announcement days between July 2009 and June 2016. The independent variables are the identified surprise changes in the three monetary policy dimensions, scaled such that an increase corresponds to a monetary policy tightening. The "NIRP Period" starts on June 11, 2014, when the ECB introduced the negative deposit facility rate; the "Normal Period" denotes the period prior to June 11, 2014. Coefficients are in units of percentage points per standard deviation change of the monetary policy surprise. T-statistics based on HAC-consistent standard errors are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

Source: Bräuning & Wu (2017)

Also Arteta et al. (2016), in line with Bräuning & Wu (2017), found a much stronger reaction of NEER after NIRP rather than in case of conventional rate cuts[12]. Eisenschmidt and Smets (2019) suggest that the signalling effect due to removal of the non-negativity restriction may lead to larger effects on the exchange rate.

[12] Actually, the study by Arteta et al. (2016) was severely biased by the January 2015 announcement of the Swiss National Bank. As we know, the rate cut was accompanied by the decision to abandon the exchange rate ceiling of the Swiss Franc vis-à-vis the Euro, leading to a strong appreciation of the former, that inevitably influenced the overall average reaction. For this reason, results should be taken with caution.

Another relevant contribution to the topic is the one by Lane (2019), that, on the same wavelength of Eisenschmidt and Smets (2019), provides evidence of a changing behaviour of the EUR/USD exchange rate since the introduction of NIRP. In particular, the author shows that the sensitivity to a decline of rate expectations increased over time and more than doubled compared to pre-NIRP period. From this analysis it seems evident that NIRP can be able to bring an enhanced effect on the exchange rate but, if we look at the situation from a broader perspective, the specific merit of NIRP is not so ascertained. In fact, Ferrari et al. (2017) employed a cross-countries event study and found that the sensitivity of exchange rates to monetary policy is growing over time, but this rising FX impact can be observed for both central banks adopting unconventional monetary policies and those not involved in this practice.

To conclude, we can affirm that, apart from specific exceptions, negative rate policies affect the exchange rates (ceteris paribus) depreciating the local currency, as it typically happens also following rate cuts in positive territory. There is, instead, still open discussion about the magnitude of the effects of NIRP in comparison to conventional periods.

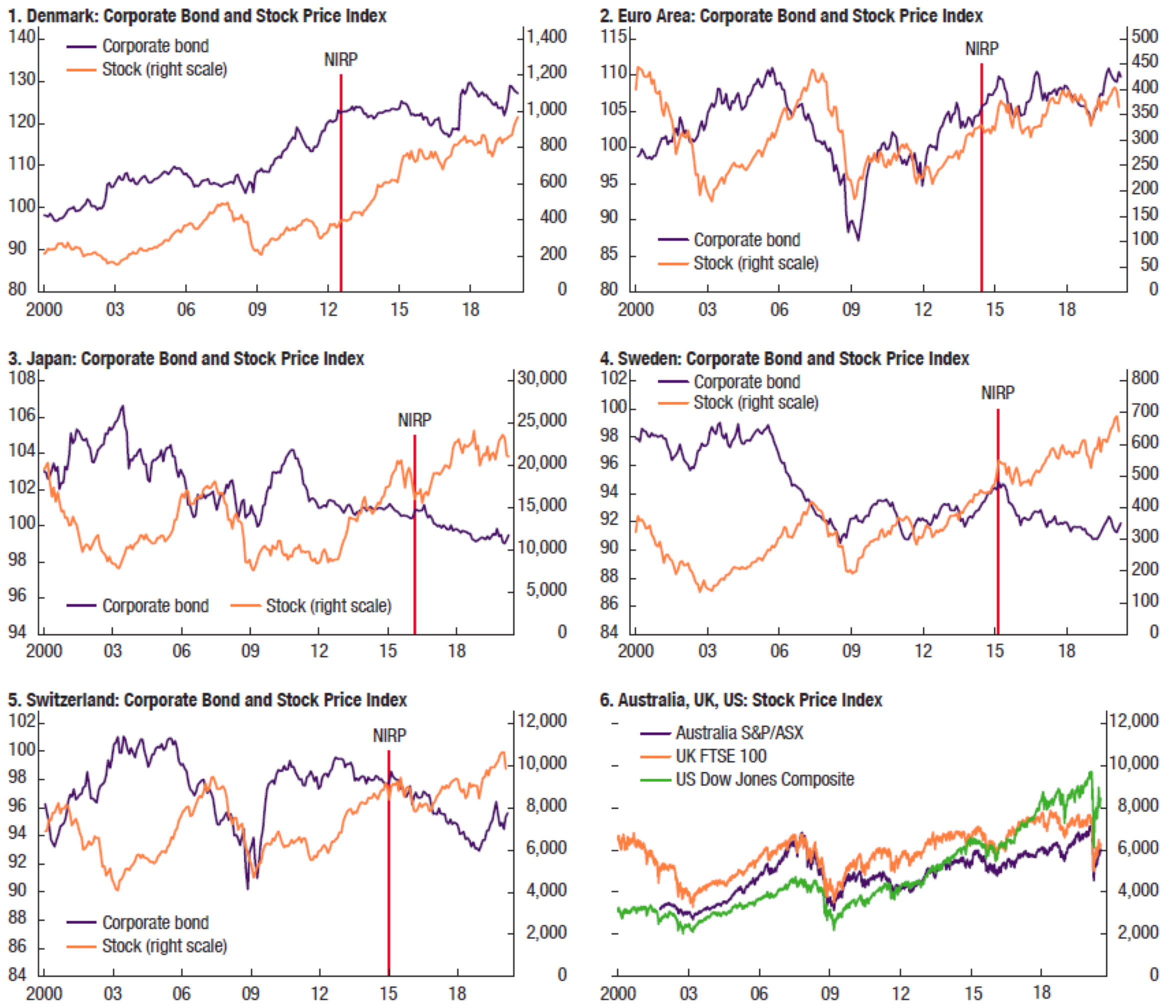
2.2.4. Other Risky Assets

We have previously claimed that the decrease in risk-free rates induced by NIRP has a natural and direct effect also on risky asset prices, leading in principle to an appreciation of both stock and corporate bonds. However, as for the empirical evidence, you can see in Figure 2.15 that stock prices generally reacted positively while corporate bonds behaved differently across countries.

Starting from corporate bonds, we notice a slight appreciation after NIRP in Denmark and the Euro area, whereas prices decline in Switzerland, Japan and Sweden. Composition effects that can impact corporate bond indices of different countries in diverse ways may be a possible, at least partial, explanation of these contrasting results. NIRP, as lower rates in general, entails among its effects an increased incentive for firms to raise external funding. This incentive tends to be appealing in particular for not top rating companies, that are more sensitive to interest rates. This, in turn, may lead to a worsened overall rating of the investment grade corporate bond indices, due to a higher relative weight of companies with not excellent rating. In some countries, this mechanism may have been more present, leading to lower prices of bond indexes, that reflect the higher riskiness expressed by the worse rating.

As for equity prices, we observe an appreciation in all the considered NIRP countries; this trend is common to the main stock indexes in no-NIRP countries, such as the US and the UK.

Figure 2.15: Corporate bonds and stock prices with NIRP



Source: IMF (2021)

After this graphical overview, we investigate the papers that adopt quantitative approaches. Boucinha & Burlon (2020), identify a contribution of NIRP equal to 3 percentage points of the overall equity prices increase between June 2014 and the end of 2019, in the Euro area. Actually, this result is probably conservative because it accounts only for the direct impact through the reduction of the risk-free used in the discount rate; instead, we know that NIRP has also encouraged risk-taking and produced confidence effects, so reducing the equity risk premia, and it has actively participated in stimulating the economy, raising earnings expectations.

In addition to the contribution by Boucinha & Burlon (2020), we resort once again to high-frequency studies, referring in particular to the work by Bräuning & Wu (2017), who provide interesting findings. As shown in Table 2.5 (see in particular the "effect of target surprise"), the reaction of stock markets has been very different before NIRP vs during NIRP (the p-values very close to zero testify this observation). A rate cut surprisingly lead to a contraction of stock prices before the introduction of negative DFR, while the response is positive and statistically significant during NIRP.
The authors give as a possible explanation the fact that, in particular in crisis periods, rate cuts may be perceived by economic agents as a vehicle of pessimistic information released by central banks. Basically, the idea is that, if the ECB provides further accommodation, then the situation may be even worse than realised and expected and this produces, in turn, a flight away from risky assets such as equities. This is what may have happened during the GFC and the sovereign debt crisis, in the pre-NIRP period, potentially explaining the contraction of stock prices following rate cuts.

Table 2.5: Effects of monetary policy shocks on stock prices

	Euro Area	Country-Level Stock Indices			
	Stoxx50 (1)	Germany (2)	France (3)	Spain (4)	Italy (5)
Effect of Target Surprise					
Pre-NIRP Period	0.230	0.173	0.272	0.287	0.170
	(1.32)	(0.87)	(1.45)	(1.47)	(0.71)
NIRP Period	-1.162***	-0.889***	-1.143***	-0.975***	-1.219***
	(-4.13)	(-2.74)	(-3.92)	(-3.54)	(-3.23)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.000	0.005	0.000	0.000	0.002
Effect of Path Surprise					
Pre-NIRP Period	0.472*	0.418	0.502*	0.594	0.679
	(1.76)	(1.63)	(1.88)	(1.54)	(1.65)
NIRP Period	-0.480***	-0.473***	-0.458***	-0.354***	-0.506*
	(-4.82)	(-4.69)	(-4.67)	(-3.32)	(-1.78)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.001	0.001	0.001	0.018	0.018
Effect of Term Surprise					
Pre-NIRP Period	0.776***	0.603***	0.785***	0.911***	1.039***
	(3.73)	(3.32)	(3.98)	(2.99)	(3.59)
NIRP Period	-0.964***	-1.036***	-0.994***	-0.593**	-0.748*
	(-3.46)	(-2.86)	(-3.61)	(-2.40)	(-1.83)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.000	0.000	0.000	0.000	0.000
Observations	78	78	78	78	78
R-squared	0.397	0.361	0.410	0.313	0.337

Notes. This table shows the estimated coefficients from regressions where the dependent variables are the log changes of stock indices on the ECB announcement days between July 2009 and June 2016. The independent variables are the identified surprise changes in the three monetary policy dimensions, scaled such that an increase corresponds to a monetary policy tightening. The "NIRP Period" starts on June 11, 2014, when the ECB introduced the negative DFR; the "pre-NIRP Period" denotes the period prior to June 11, 2014. Coefficients are in units of percentage points per standard deviation change of the monetary policy surprise. T-statistics based on HAC-consistent standard errors are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

Source: Bräuning & Wu (2017)

Finally, as for corporate bond yields, Bräuning & Wu (2017) found, instead, results with limited statistical significance, confirming the difficulty to give a clear assessment of the impact of NIRP on corporate bonds. In particular, while government bond yields reacted as expected to rate cuts, the evidence on corporate bond yields is affected by widening credit spreads, that can be in principle quite counterintuitive[13].

[13] The risk taking attitude spurred by rate cuts should compress risk premia in general, and so also credit spreads. However, as for corporate bond yields, there is no empirical evidence of this behaviour.

2.3. Empirical evidence: bank lending channel

After having described the effects of NIRP on financial markets, in order to complement the empirical analysis it is interesting to deepen how the second macro-channel, the banking sector, reacted.

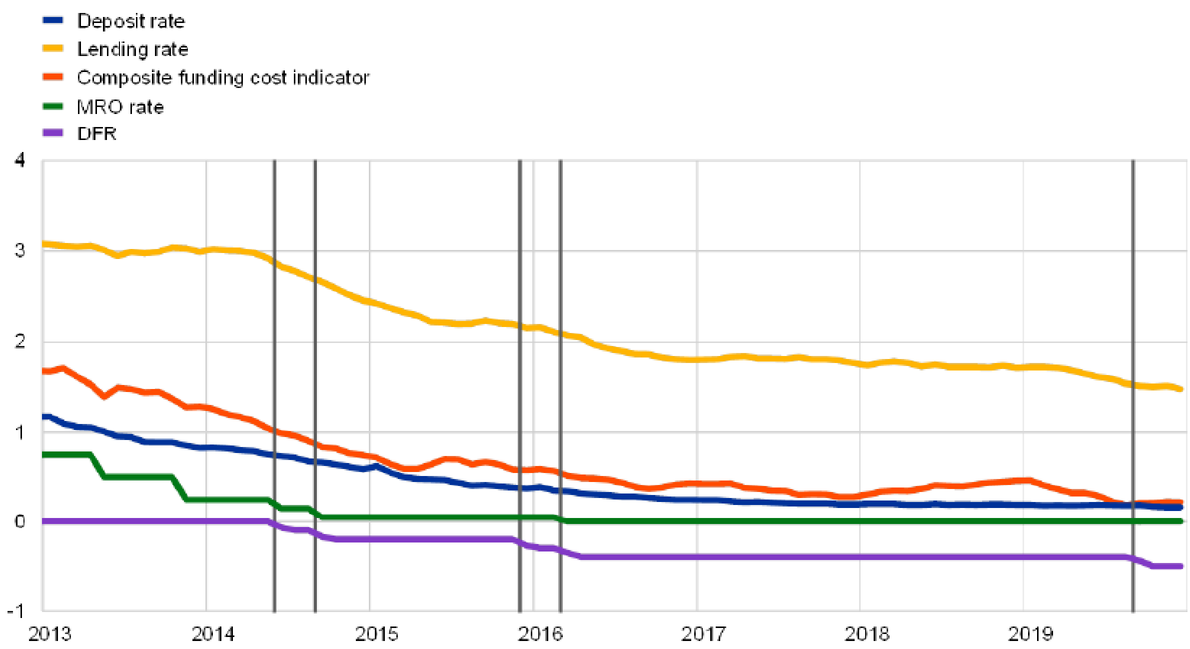
The typical transmission mechanism of rate cuts envisages a decrease of lending rates, possible thanks to the reduced funding costs for banks. Lower loan rates, in turn, can stimulate credit demand, with the consequent positive effects on the overall economy. This is the traditional interest rate channel, which seems to work also under NIRP, even though some peculiarities emerge when interest rates lie at ultra-low levels, and even more when they enter in negative territory. These dynamics will be discussed in the following, together with additional channels that may arise or may be enhanced in the new environment. Moreover, the attention of our analysis will be devoted also to possible side effects as concerns bank profitability, that may undermine the effectiveness of the pass through in terms of loan rates and lending volumes.

2.3.1. Banks funding costs and deposit rates

NIRP, in line with conventional rate cuts, entails an easing of financing conditions, in the first place for commercial banks and then, in the presence of a functioning transmission mechanism through the banking system, also for households and corporations, that can enjoy lower rates on loans.

Starting from the funding cost for banks, we can observe that this has decreased since the introduction of NIRP. In Figure 2.16, for example, Boucinha & Burlon (2020) show in red the decline of the composite funding cost indicator for Euro area banks. The downtrend is quite natural and coherent with the general reduction of rates on the financial markets. In fact, among the sources of funding of commercial banks, we find debt securities and money market funds, whose interest rates have been lowered by NIRP, as previously explained. Other key funding options, such as household and corporate deposits, deserve a detailed discussion, given that some peculiarities emerge close to the zero lower bound.

Figure 2.16: Policy rates and banking sector rates in the Euro area



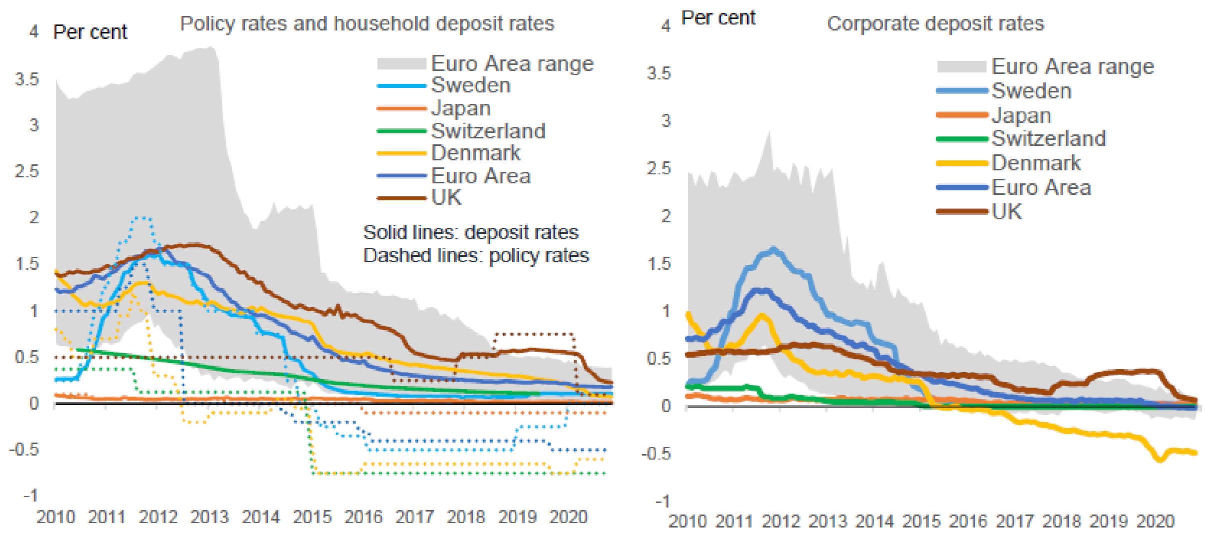
The vertical black lines indicate the five cuts in the DFR into negative territory, from 0 to -0.1% in June 2014, from -0.1% to -0.2% in September 2014, from -0.2% to -0.3% in December 2015, from -0.3% to -0.4% in March 2016, and from -0.4% to -0.5% in September 2019.

Source: Boucinha & Burlon (2020)

A downward rigidity close to zero seems to characterise deposit rates, in particular as concerns household deposits. The constraint appears, instead, less strict for corporate deposits, with experiences of negative rates, for example, in Denmark and in some Euro area countries. These are visible on the right panel in Figure 2.17, while the left panel highlights the inflexibility of the zero lower bound for household deposits (see how the solid lines representing the different countries are bounded by zero). However, the IMF (2021) notices that, actually, the ZLB is just a nominal illusion for household depositors, given that banks tend to charge more fees and commissions, that are also opaquer compared to interest rate variations.

The different behaviour in case of households or corporate deposits rates is due to both the presence of legal concerns in imposing negative rates to households and the lower perceived risk of withdrawal for the corporate segment, given that switching into paper currency is costlier for companies and, in general, for agents with large cash holdings.

Figure 2.17: Policy rates and measures of household & corporate deposit rates



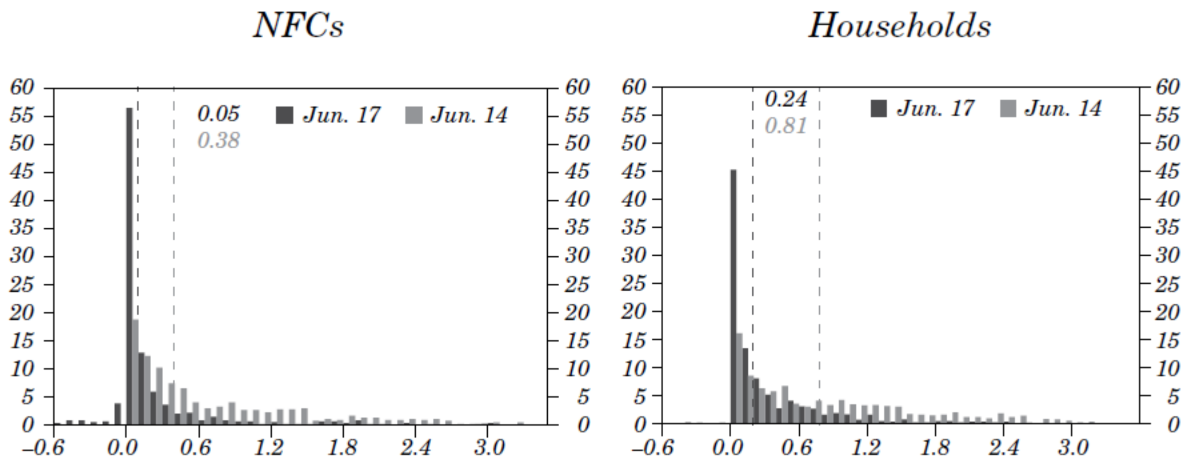
Notes. Policy rates definitions: Sweden: repo rate. Japan: target for uncollateralised overnight rate until December 2015; rate on Complementary Deposit Facility thereafter. Switzerland: average of SNB target range until June 2019, SNB policy rate thereafter. Denmark: certificate of deposit rate. Euro Area: rate on main refinancing operations until May 2012, deposit facility rate thereafter. UK: Bank Rate. Deposit rates definitions: Euro Area, Denmark, Sweden and UK are weighted-average interest rate on outstanding stock of MFI deposits. Switzerland: for households, average interest rate on domestic customer deposits, for corporates simple average of median interest rate for private clients on a) payment accounts without withdrawal restrictions and b) high value (>100,000 CHF) 1 year term deposit. Japan: simple average of a) average posted interest rate on ordinary deposits and b) effective rate on low value (<3m Yen) time deposits for households, effective rate on high value (>10m Yen) time deposits for corporates.

Source: Tenreyro (2021)

Focusing on the Euro area, we provide further empirical evidence in order to enrich the discussion about household and corporate deposit rates. Figure 2.18 depicts how the ZLB represents a "special" level both for non-financial corporations (NFCs) and households deposit rates. However, although both the distributions tend to accumulate near zero, corporate rates at some point started to explore negative territories (see in particular the presence of negative rates in June 2017 distribution), while household rates continued to pile up close to zero as if it was an uncrossable limit.

Figure 2.19, instead, complements the analysis showing the proportion of deposit rates that exhibited negative values at different instants of time. As we expected, household deposit rates were basically always positive or null, while corporate deposits with negative rates started to appear around early 2015 and they gradually grew in terms of relative weight over the total of NFC deposits as time passed.

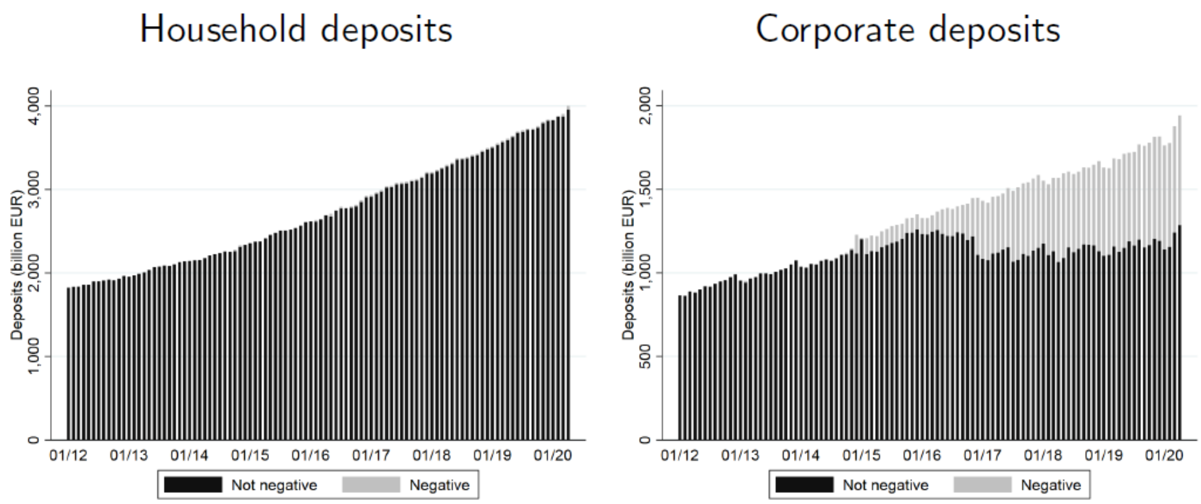
Figure 2.18: Distribution of deposit rates (corporations and households), across Euro area banks



Notes. Dashed lines represent mean of distribution.

Source: Eisenschmidt & Smets (2019)

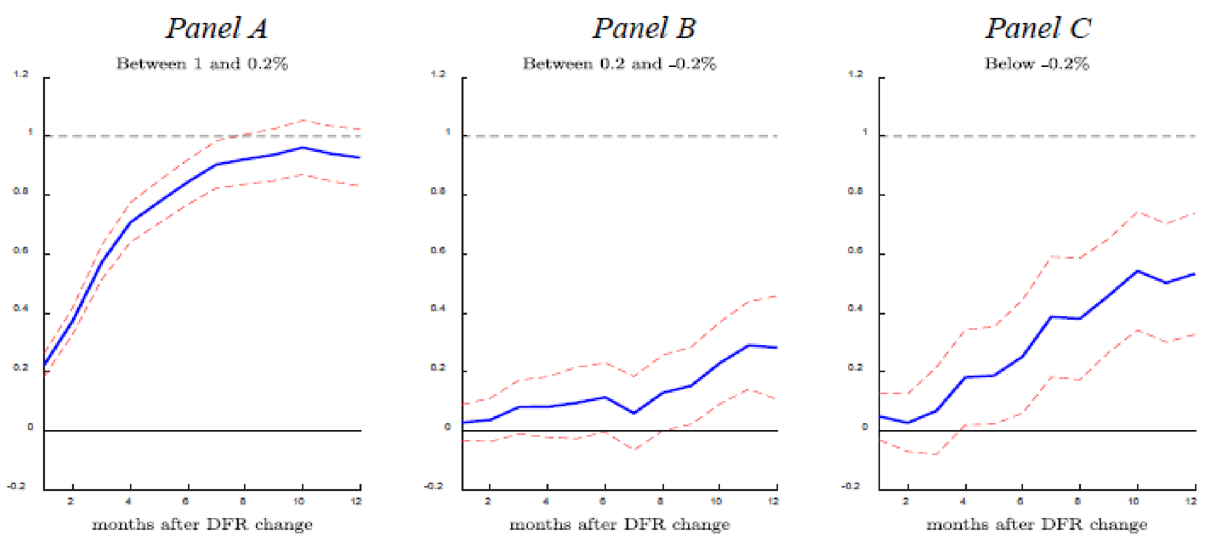
Figure 2.19: Volume of Euro area overnight deposits with negative and not negative rates



Source: Heider et al. (2021)

Looking at Figure 2.19, an interesting dynamic about corporate deposit rates emerges quite clearly. Considering the growth over time of the volume of NFCs deposits with negative rates, the decision to apply negative rates to corporate depositors seems to be related to the depth and perceived persistency of negative policy rates. Altavilla et al. (2019) studied this phenomenon and found that indeed the pass-through to corporate deposit rates was stronger once the ECB moved quite deeply in negative territory and NIRP consequently stopped to be regarded as a transitory event. Figure 2.20 shows the impulse response functions, up to 12 months delay, for corporate deposit rates following a change in the DFR (see the caption of the figure for more details). We can notice that, until the DFR is robustly positive, the policy rate change is transmitted almost 100% to corporate deposits (panel A). On the contrary, the response is much weaker when the DFR is between 0.2% and -0.2% (panel B). Panel C, finally, confirms that the pass-through to corporate deposit rates regains force once the DFR is deeply negative, even though the transmission is significantly reduced compared to policy rate changes in positive field.

Figure 2.20: Cumulated response of corporate deposit rates to DFR cuts



The figure reports the coefficients β_h resulting from the regression $\Delta R_{i,t+h} = \alpha_{i,h} + \beta_h * \Delta DFR_t + \epsilon_{i,t+h}$, for h=1,...,12. $\Delta R_{i,t+h}$ is the change in the interest rates on deposits of bank i between t and t+h, the variable ΔDFR represents the change in the interest rate on liquidity deposited at the central bank. The coefficient β_h gives the cumulated response of banks' interest rates on deposits up to time t+h to a change in deposit facility rate at time t. The blue solid line reports the coefficients β_h while the red dashed lines report the 95% confidence intervals for each horizon h with robust standard errors.

Source: Altavilla et al. (2019)

Summing up, the evidence presented so far testifies a peculiar behaviour of banks when deposit rates approach the ZLB. The downward rigidity in case of household deposits weakens the pass-through of monetary policy compared to positive rate cuts, given that it entails a less pronounced easing of bank funding costs, in particular for banks heavily relying on retail deposits. This may translate in lower net interest margins (in case lending rates are reduced consistently with policy actions) and, in turn, may negatively affect banks net worth, as better explained in paragraph 2.3.4. As for corporate deposits, instead, additional considerations are necessary to judge the overall impact on funding conditions. In fact, it is relevant to assess if negative deposit rates, that for sure imply a reduction in funding costs, can nevertheless generate significant deposit outflows, that would be absolutely negative for banks self-financing. Altavilla et al. (2019), in their analysis on the Euro area banking sector, found that no deposit outflows happened even when negative rates are charged.

Moreover, they provide also additional details to outline the dynamics of the observed phenomenon. They argue that a key motivation to explain the absent outflow from deposits charging negative rates lies in the market power of those banks that can afford to set negative corporate deposits rates. The first element to clarify is therefore the identikit of banks that result to be more propense to charge negative rates. Altavilla et al. (2019) identified *bank health* as the main driver in the decision to apply below zero deposit rates. In fact, the presence of sound balance sheets guarantees to virtuous banks the market power to transfer on depositors the "tax" imposed by a negative DFR, without experiencing a significant cash outflow. This happens because, in particular when the demand for safe assets is high and the supply is characterised by deeply negative yields, agents are willing to rely on sound banks even at negative rates, as they represent a valid safe option. In practice, this explains why mainly healthy banks charge negative rates and those banks do not see deposit outflows even after deteriorating conditions for corporate depositors.

Table 2.6 provides empirical evidence supporting the considerations about the relevance of bank health. In particular, columns 2, 3 and 4 confirm with statistical significance that sound banks are more likely to charge negative rates. The variables used as proxy of bank health are *Non-investment grade* (dummy variable), *CDS spread, NPL ratio;* the negative coefficients mean that the dependent variable, *Probability that deposit rate < 0,* increases if a bank is rated as investment grade, is characterised by a lower default risk (measured by the CDS spread) and is affected by a lower presence of non-performing loans among its assets. This is perfectly in line with the thesis that negative deposit rates are more common for healthy banks.

Stressed country and *Excess liquidity* are other relevant variables in the definition of the probability of negative rates: banks in non-stressed countries are more willing to set below zero deposit rates and the same is true for banks with higher excess liquidity, coherently with the idea that commercial banks consider negative deposit rates as a mean to offset the charges due to the negative DFR (charges that are more distressing higher the excess reserves held).

Table 2.6: Bank characteristics and probability to charge negative corporate deposit rates

Dependent Variable: Probability that deposit rate<0	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stressed country	-2.988***				-0.739			
	(1.020)				(1.038)			
Non-investment grade		-4.046***			-2.771***	-3.288***	-3.764***	-1.842**
		(1.054)			(0.947)	(1.043)	(1.120)	(0.874)
CDS spread			-0.003***					
			(0.001)					
NPL ratio				-0.117***	-0.021			
				(0.037)	(0.046)			
Excess liquidity					0.545***	0.515***	0.532***	0.577***
					(0.142)	(0.133)	(0.114)	(0.121)
Non-investment grade*Exc. Liq.								-0.854***
								(0.174)
Assets					1.094**	1.144**	4.186**	4.040**
					(0.466)	(0.523)	(1.611)	(1.639)
ROA					-0.204	0.009	-0.131	-0.084
					(0.204)	(0.188)	(0.161)	(0.158)
Foreign branch/subs.					-0.347	-1.829		
					(1.001)	(1.173)		
Deposit ratio					-0.076	-0.045	-0.210	-0.199
					(0.075)	(0.073)	(0.127)	(0.126)

This table provides estimates of linear probability models in which the dependent variable takes value equal to 100 if a bank charges negative rates on non-financial corporations' deposits in month *t* and to zero if the bank offers positive rates. A range of bank characteristics is considered. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Altavilla et al. (2019)

Table 2.7, instead, focuses on the possible presence of deposit outflows. The coefficient in row 1, column 1 testifies that banks charging negative rates did not experience deposit outflows; indeed, we find a positive and statistically significant relationship between the growth in deposits and the decision to set negative rates[14]. This is due to the fact that negative rates are typical of healthy banks with strong market power that are also the ones with higher deposit growth, as suggested by the negative coefficient between *NPL ratio* and the dependent variable (higher the proportion of non-performing loans, lower the soundness of a bank and lower the experienced deposit growth).

Table 2.7: Bank characteristics and growth in deposits

Dependent Variable: Growth in deposits since May 2014	(1) until Jun-15	(2) until Nov-19	(3) until Nov-19
Bank charges negative rates*100	0.496***	0.297*	0.285*
	(0.125)	(0.150)	(0.149)
High Pass-Through Bank *100			
NPL ratio in May 2014	-1.438**	-1.409*	-1.411*
	(0.563)	(0.732)	(0.748)
Assets in May 2014	1.340	-4.574	-4.696
	(2.789)	(4.304)	(4.531)
ROA in May 2014	-4.192*	0.193	0.177
	(2.286)	(4.048)	(3.954)
Foreign branch/subs.	-12.710	-20.601*	-22.476*
	(8.268)	(12.382)	(12.665)

Notes. Changes in banks' deposits over the intervals indicated on top of each column are related to a dummy capturing whether a bank charges negative rates on deposits and bank NPL in May 2014, right before the start of the NIRP and other bank characteristics. Standard errors are corrected for heteroskedasticity. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Altavilla et al. (2019)

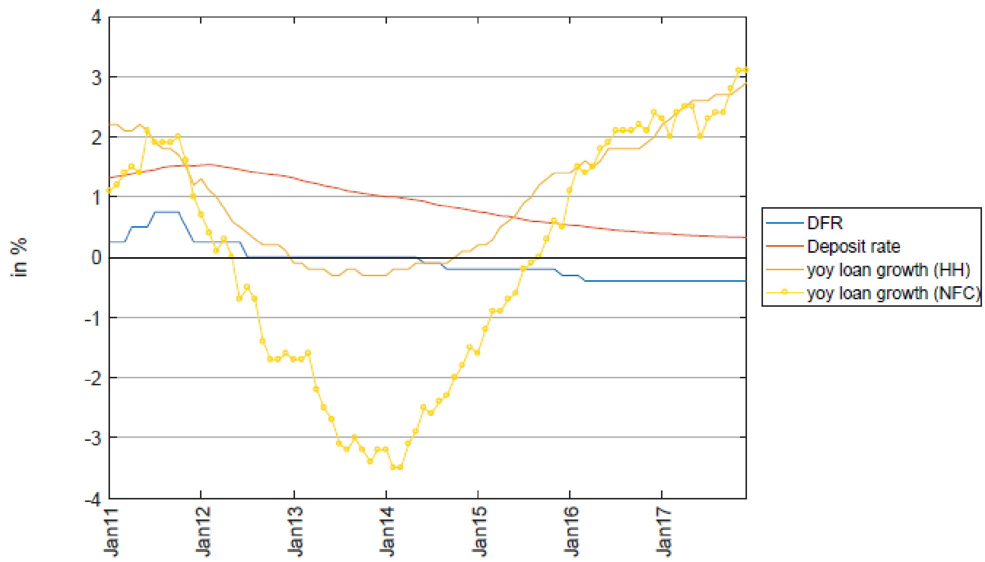
In summary, we can conclude that the pass through of NIRP to corporate deposit rates, even though less pronounced compared to rate cuts in positive territory, contributes to the reduction of commercial bank funding costs. We have also ascertained that this has happened without a contraction in funding, in particular thanks to the role of healthy banks. The next step is to analyse the transmission from banks to the economy, namely to lending rates and volume of loans supply.

[14] *Bank charges negative rates* is a dummy variable. When a bank set negative deposit rate, the dummy takes value equal to 1 and the amount of deposits grows, as shown by the positive coefficients in the first row.

2.3.2. Lending rates and loans volume

Figure 2.16 anticipated that average lending rates in the Euro area decreased following the introduction of NIRP. Figure 2.21, instead, shows that also the growth of loans, both to households and non-financial corporations (gold & yellow lines), reacted positively to negative rate policies, inverting the trend of year over year change precisely from 2014. In this paragraph, we discuss the underlying dynamics of both the phenomenon, relying on the empirical evidence collected so far.

Figure 2.21: Loan growth in the Euro area



Source: Klein (2020)

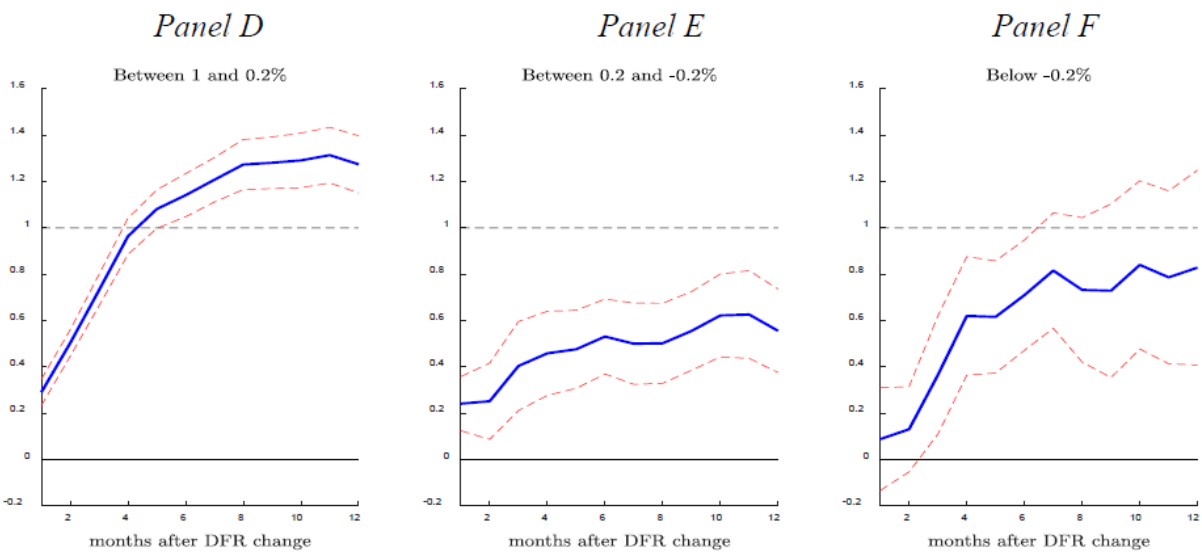
In principle, until a rate cut leads to a reduction of the overall bank funding costs, it creates room for decreasing loan rates without squeezing interest margins. Then, competitive pressure among banks may entail a further reduction of lending rates that would negatively affect bank profitability[15] and, in turn, also the net worth. This, in presence of restricting capital constraints, would undermine the willingness to extend credit supply. However, there is no evidence that somewhere the reversal rate (Brunnermeier & Koby, 2018) has been reached, so the threat of a rate cut contractionary for lending has still not materialised.

[15] See paragraph 2.3.4. for a thorough analysis of the impact of NIRP on bank profitability

The literature tends to agree that NIRP decreased lending rates and spurred the growth of credit supply, but the intensity of the effect and the comparison with the impact of standard rate cuts are still debated, with different results according to the time horizon and the methodologies used.

Altavilla et al. (2019), for example, found a consistent pass-through of NIRP to lending rates, but lower than in "normal" times. Figure 2.22 shows impulse response functions of Euro area lending rates to DFR changes, as previously explained in case of corporate deposit rates. We can see that, in particular once the DFR is pushed further in negative territory (panel C), the cumulated reaction of loan rates is significant but decisively lower than after rate cuts in positive field (panel A).

Figure 2.22: Cumulated response of lending rates to DFR cuts



The figure reports the coefficients β_h resulting from the regression $\Delta R_{i,t+h} = \alpha_{i,h} + \beta_h * \Delta DFR_t + \epsilon_{i,t+h}$, for h=1,...,12. $\Delta R_{i,t+h}$ is the change in the interest rates on loans of bank i between t and t+h, the variable ΔDFR represents the change in the interest rate on liquidity deposited at the central bank. The coefficient β_h gives the cumulated response of banks' interest rates on loans up to time t+h to a change in deposit facility rate at time t. The blue solid line reports the coefficients β_h while the red dashed lines report the 95% confidence intervals for each horizon h with robust standard errors.

Source: Altavilla et al. (2019)

Eisenschmidt & Smets (2019), instead, argue that NIRP did not brought relevant changes in the pass-through to bank lending rates. This thesis is supported by the results of their econometric application, that you can find in Table 2.8.

Column 1 shows the coefficient of reaction of loan rates to DFR changes: as expected, the relationship is positive (a DFR cut decreases lending rates), and it is also statistically significant at 1% level. In column 2, instead, we see what happens introducing an interaction term between DFR changes and a dummy variable recognising NIRP periods from pre-NIRP. This term (row 2) results to be not statistically significant, meaning that there is no evidence that being during NIRP affects in some way the pass-through of DFR cuts to interest rates on loans.

Table 2.8: Pass-through of DFR changes to composite loan rates

	(1)	(2)
Change DFR	0.611***	0.625***
	(0.068)	(0.145)
Change DFR x NIRP		0.609
		(0.572)
Change DFR x deposit share x NIRP		-0.009
		(0.009)

Notes. *p<0.1; **p<0.05; ***p<0.01. Sample covers 59 German banks, quarterly data from 2009Q1 to 2016Q3.

Source: Eisenschmidt & Smets (2019)

The third approach that provides interesting findings for our discussion is the one by Bräuning & Wu (2017), who realised that, in some cases, the impact of NIRP on loan rates and also on credit growth tends to be stronger than in "normal" times. We have already presented their high-frequency methodology but, as concerns bank lending in the Euro area, they extend the time horizon of observation to one-month reaction, given that the response cannot be as immediate as in case of financial markets. The variable object of the analysis is corporate bank lending, both in terms of interest rates and volumes, and distinguishing between short-term (3 months up to 1 year maturity) and longer-term loans (3 to 5 years maturity). Looking at Table 2.9 and focusing on the target rate factor during NIRP, we find an effective transmission to short-term rates, but the most outstanding result is on longer-term rates. The reaction of the latter to target rate changes becomes statistically significant and much stronger than before NIRP. In fact, also the t-test returns a low p-value (0.027) that confirms how the coefficients of reaction of long-term rates are significantly different before and during NIRP.

As for loan volumes, the comment is similar to that on interest rates. We can notice a statistically significant transmission to both short-term and long-term loans during NIRP. However, it is at longer maturities that the increase of loan origination after a rate cut is particularly relevant and significantly different from what happens in pre-NIRP period (the p-value from the equal coefficients t-test is close to zero).

Table 2.9: Effect of Monetary Policy Shocks on Corporate Bank Lending

	Loan Interest Rate		(Log) Loan Volume	
	Short-Term (1)	Longer-Term (2)	Short-Term (3)	Longer-Term (4)
Effect of Target Surprise				
Pre-NIRP Period	3.072*	1.233	-6.372	-1.708
	(1.79)	(0.86)	(-1.64)	(-0.54)
NIRP Period	3.316**	9.484***	-13.445***	-25.447***
	(2.36)	(2.75)	(-3.51)	(-6.52)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.912	0.027	0.196	0.000
Effect of Path Surprise				
Pre-NIRP Period	-1.697	-2.488	-0.934	4.508
	(-0.65)	(-0.75)	(-0.22)	(1.14)
NIRP Period	1.419**	5.915***	-2.673	-1.521
	(2.32)	(3.71)	(-1.23)	(-0.98)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.246	0.023	0.713	0.155
Effect of Term Surprise				
Pre-NIRP Period	3.803	4.302*	-5.369	-0.437
	(1.47)	(1.96))	(-1.46)	(-0.15)
NIRP Period	2.721*	3.225	-8.445*	-5.440
	(1.74)	(1.18)	(-1.75)	(-1.15)
P-val for $\beta_{\text{NIRP}} = \beta_{\text{Pre-NIRP}}$	0.721	0.759	0.613	0.371
Observations	67	67	67	67
R-squared	0.157	0.183	0.132	0.125

Notes. This table shows the estimated coefficients from regressions where the dependent variables are the monthly change in interest rate of newly originated business loans and the monthly changes in the log volume of newly originated business loans in the euro area. The changes are computed from the months bracketing the ECB announcement days between July 2009 and June 2016. The independent variables are the identified surprise changes in the three monetary policy dimensions, scaled such that an increase corresponds to a monetary policy tightening. The "NIRP Period" starts on June 11, 2014, when the ECB introduced the negative deposit facility rate; the "pre-NIRP Period" denotes the period prior to June 11, 2014. For the responses of interest rates, the coefficients are in units of basis points per standard deviation change of the monetary policy surprise. For the responses of volumes, the coefficients are in units of percent per standard deviation change of the monetary policy surprise. *** (**) [*] denote statistical significance at 1% (5%) [10%] level.

Source: Bräuning & Wu (2017)

A possible explanation of the peculiar transmission during NIRP lies in the consequences that this unconventional monetary policy tool generates on the banking sector. We have already explained that the charge imposed on excess reserves and, in general, the possible pressure on interest margins and profitability, may spur risk taking and search for yield behaviours. This translates not only in the choice of longer-term and riskier assets on the financial markets, but also in the origination of more loans, in particular with longer maturities (and sometimes to riskier borrowers), in order to reach higher margins, as typically ensured by increasing maturity mismatch.

The empirical results we have presented testify that, as anticipated, the evidence about the level of pass-through of NIRP to bank lending is quite heterogenous. Several studies, with the aim of better understanding the relationship between NIRP and bank behaviour, have tried to identify some differentiating characteristics that tend to stimulate a stronger pass-through to lending for some banks rather than others. In particular, the most common strategy has been to compare banks more exposed to the effects of negative rates to those less exposed, identifying the exposure mainly as reliance on deposit funding or, in some cases, in terms of level of excess liquidity.

Starting from the former, banks relying heavily on retail deposits are considered more exposed to NIRP given the stickiness of households deposit rates. In fact, the limited reduction of funding costs may exacerbate competitiveness of these banks or negatively affect profitability because of tighter margins. As for the empirical evidence, the literature, summarised in Table A2 in annex, is characterised by mixed results as concerns the comparison between more and less exposed banks (that here means banks with a higher or lower reliance on deposit funding). Several studies found more accommodative responses by more exposed banks, which try to compensate the lower interest margins lending more (sometimes further lowering rates to reach the objective) and, in some cases, also to riskier borrowers. On the opposite, a smaller number of approaches has identified a weaker credit supply from more exposed banks. The interpretation of this result can be quite straightforward and in line with the traditional interest channel, given that less exposed banks enjoy a more pronounced reduction of funding costs and have therefore more room to decrease loan rates and attract higher credit demand, that can in turn translate in a stronger growth of loan origination.

Moving, instead, to the role of excess liquidity, banks with higher excess reserves are more exposed to negative rates since it is larger the impact of the charge imposed by NIRP. In line with the portfolio rebalancing channel, Bottero et al. (2019) report that commercial banks with (ex-ante) more liquid assets are characterised by a higher loan growth and the extension of lending also to riskier firms.

In conclusion, we can state that for sure the pass-through of monetary policy to lending conditions is not unimpeded under NIRP, while the debate is still open and the evidence rather heterogenous as regards the level of transmission compared to standard rate cuts. Moreover, also as for the identification of the characteristics of the banking sector that stimulate more credit supply, the discussion is characterised by contrasting and coexisting results in the literature.

2.3.3. Additional channels of transmission

In the previous paragraph, the focus was mainly, even if not only, on the traditional interest rate channel, that works through the reduction of bank funding costs passed onto lending rates. Lower rates on loans can, in turn, stimulate a demand-driven increase of credit origination. However, the effects of NIRP through the banking system involve also other transmission mechanisms, that are peculiar of negative rates or, in any case, enhanced compared to conventional policies.

The first of these channels is the bank lending one, intended in terms of supply-driven rise of credit origination. In fact, the sensible increase of loan volumes after NIRP announcements, shown for example in Table 2.9, is due to both a higher credit demand, stimulated by reduced lending rates, and a risen propensity of commercial banks to originate loans. As explained talking about the role of excess liquidity, banks are spurred to an enhanced risk-taking attitude in order to reduce the “taxed” liquidity and to compensate charges on excess reserves and possible lower interest margins.

The portfolio rebalancing activity, in search for yield, entails investing in longer-term and riskier securities and originating more loans, sometimes to riskier borrowers, obviously always in a compatible way with regulatory constraints. This mechanism is therefore responsible of a supply-driven credit growth.

The second relevant channel is what Altavilla et al. (2019) define the corporate channel of monetary policy. Firms with high cash holdings at sound banks, which start to charge negative corporate deposit rates, are incentivised to rebalance their asset composition through a reduction of liquid assets and cash in favour of fixed investment. In fact, once their cash-holdings are taxed, firms revaluate some investment opportunities that, even though with not outstanding expected payoffs, appear now much more desirable, compared to keeping liquidity at negative yields. Empirical evidence of this behaviour is provided in Table 2.10. The variable main object of interest is *Exposure,* that is defined as the proportion of total assets held as cash by firms who rely on banks charging negative deposit rates. Columns 5 and 6 show the existence of a statistically significant relationship between exposure and the choice between investment[16] and cash-holdings. In particular, as argued above, ex-ante high cash-holding firms, facing negative deposit rates, tend to reduce liquid assets (coefficient -0.092) while increasing fixed investment (coefficient 0.597). This dynamic finds further confirmation in Table 2.11: firms with higher ex-ante cash holdings, subjected to negative interest rates, increase more investment in both tangible and intangible assets, while the amount of total assets stays quite stable, testifying the presence just of a balance sheet rebalancing activity from more liquid to fixed assets.

[16] The variable *Investment* is defined as the annual growth rate of fixed assets

Table 2.10: Investment vs cash-holding decision for firms highly exposed to negative deposit rates

Dependent Variable:	(1) Debt/Assets	(2) Debt/Assets	(3) Investment	(4) Debt/Assets	(5) Investment	(6) Cash-holdings
High pass-through bank*Post	0.503***	0.302***	0.974	0.511***	0.859	-0.126*
	(0.151)	(0.112)	(0.652)	(0.150)	(0.718)	(0.067)
Bank charges negative rate	-0.194	-0.137	2.621*	-0.234	-40.501***	6.655***
	(0.155)	(0.138)	(1.429)	(0.473)	(2.885)	(0.508)
Exposure				0.000	0.597***	-0.092***
				(0.006)	(0.043)	(0.007)
Cash-holdings (lag)				-0.073***	2.980***	0.554***
				(0.003)	(0.053)	(0.007)

Notes. The unit of observation is the firm-year. The sample is made of 473,213 firms from 2007 to 2018. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Altavilla et al. (2019)

Table 2.11: Balance sheet rebalancing of firms highly exposed to negative deposit rates

Dependent Variable:	(1) Growth in tangible fixed assets	(2) Growth in intangible fixed assets	(3) Total assets
Exposure	0.485***	1.610***	0.012
	(0.053)	(0.611)	(0.019)
Cash-holdings (lag)	2.327***	3.087***	0.045
	(0.103)	(0.141)	(0.030)

Notes. The unit of observation is the firm-year. The sample is made of 473,213 firms from 2007 to 2018. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Altavilla et al. (2019)

The described mechanism, indicated as corporate channel, thus represents an additional important stimulus for the real economy, generated specifically by negative rate policies. In fact, looking at Table 2.12, we can notice that high cash-holding firms do not react with a significant rebalancing activity after policy rate cuts in a low rate environment (row 1 and 2), while they do that when banks start charging negative rates (row 3 shows what already explained in the discussion of table 2.10).

Table 2.12: Rebalancing activity above and below the ZLB

Dependent Variable:	(1) Investment	(2) Cash-holdings
Exposure Low(2009-2011) * Post(2009-2011)	0.014	-0.000
	(0.021)	(0.002)
Exposure Low(2012-2013) * Post(2012-2013)	-0.021	0.000
	(0.095)	(0.006)
Exposure	0.556***	-0.089***
	(0.048)	(0.007)
Cash-holdings (lag)	2.988***	0.552***
	(0.057)	(0.007)

Notes. The unit of observation is the firm-year. The sample is made of 473,213 firms from 2007 to 2018. The variables *Exposure*Low(2009-2011)* and *Exposure *Low(2012-2013)* are a firm's cash-holdings multiplied by a dummy that takes value equal to one if a firm's bank offered deposits rates below the fifth percentile in the periods from 2009 to 2011 and from 2012 to 2013, respectively. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Altavilla et al. (2019)

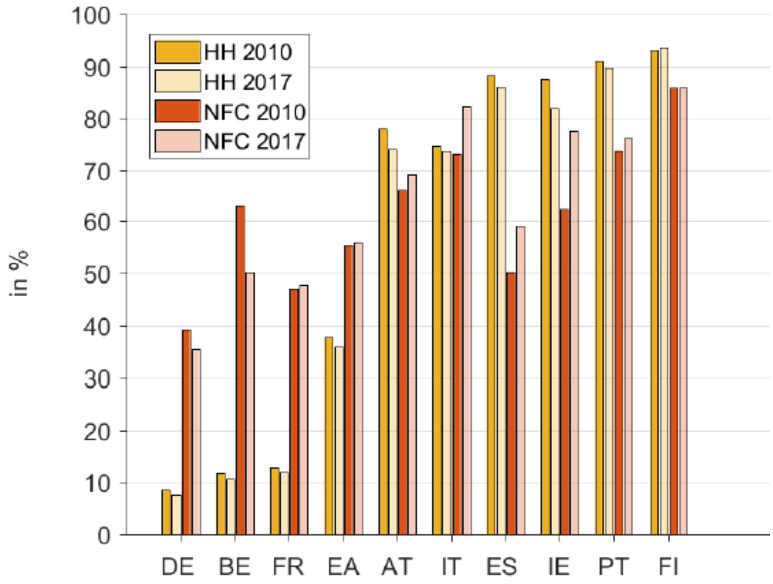
2.3.4. Bank profitability

Negative rate policies have successfully contributed to ease lending conditions and spur credit growth, as argued earlier. However, this unconventional monetary policy presents also possible side effects, such as the impact it can have on banks profitability and, in turn, on bank net worth.

Several studies agree that negative rates deteriorate banks net interest margins (NIM), while the overall effect on profitability is less clear if we take into account the other variables involved and the positive impact of NIRP on general macroeconomic conditions. Here, we propose a comprehensive discussion of these dynamics.

- We start from the net interest income, the profitability measure most directly affected by interest rate changes. The downward rigidity of household deposit rates represents a key issue as concerns interest margins. In fact, negative rates on excess reserves cannot be fully passed onto depositors, with the consequent contraction of margins. Moreover, lending rates tend to decline more than funding costs, again because of the existence of the ZLB on deposits and because of competitive pressures that push commercial banks to further cut interest rates on loans. In addition, we can notice that NIRP squeezes interest margins in a peculiar way because it induces a flattening of the yield curve, in particular when its strong impact on long-term rates is enhanced also by asset purchase programs and forward guidance. A flatter yield curve complicates bank activity since it hinders the profitability from maturity mismatch. This last effect, however, is not always very relevant, since it depends on the pricing strategy of banks. Klein (2020), for example, find a statistically insignificant impact of the term spread on interest margins of Euro area banks, explaining the result with the large share of commercial banks oriented to fixing short-term or variable rates on loans. Figure 2.23 depicts how, in some Euro area countries, this kind of interest rate fixation covers the large majority of outstanding loans to the non-financial private sector. As a consequence, in this case, the impact of NIRP does not come much from the flattening of the yield curve, rather directly from the decline of short-term rates. To complement the analysis, we also notice that a high proportion of variable rates on loans limits one of the positive effects of policy rate cuts, that consists in continuing to receive high[17] interests payments on fixed-rate loans, until their maturity.

Figure 2.23: Share of flexible and short-term rate fixation in outstanding loans



Notes. The figure shows data for Q4 2010 and Q4 2017, taken from Eurosystem MFI Balance sheet statistics. Short-term rates regard loans to non-financial private sector, up to 1 year maturity. The graph shows a sub-sample of countries belonging to the euro area.

Source: Klein (2020)

[17] Here the term "high" is not referred to absolute terms, but it means in line with the previous (higher) level of policy rates.

The contraction of NIM is supported by theoretical reasonings and, in general, is empirically verified. In particular, Klein (2020) testifies that, given the peculiarities of negative rates, the decline of NIM following a rate cut is particularly pronounced during NIRP. Table 2.13 shows, with statistical significance, that the response of the net interest margin to rate changes is much stronger when short-term rates[18] are in negative territory. In fact, we notice a much larger coefficient in row 3 compared to the ones in row 1 and 2, that refer, respectively, to the response of NIM considering the whole sample form July 2007 to December 2018 and considering the sub-sample characterised by a low short-term rate (0 ≤ 3-month OIS ≤ 1.25%).

Table 2.13: Response of net interest margin to interest rate changes

Dependent variable:	*NIM*
$Short\text{-}term\ rate_{whole\_sample}$	**0.9****
$Short\text{-}term\ rate_{low}$	**2.8*****
$Short\text{-}term\ rate_{negative}$	**6.9*****

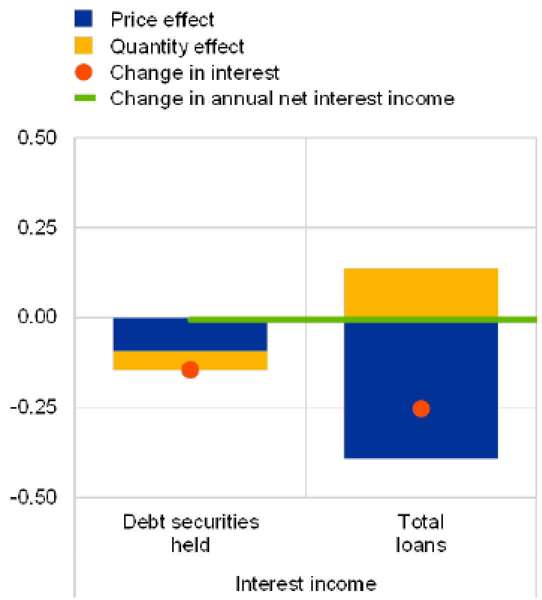
Note. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Source: Klein (2020)

As for the net interest income, instead, the negative effect of squeezed margins is, at least partially, counterbalanced by the growth of loan origination. This is what Boucinha & Burlon (2020) identify with the term "Quantity effect" in Figure 2.24. Looking at the interest income from loans, the (negative) actual result is represented by the red point, that is the algebraic sum of the negative price effect (lower NIM) and the positive quantity effect (higher credit supply).

[18] Klein adopts the 3-month OIS (overnight index swap) as short-term rate, that represents a good proxy of policy rates level.

Figure 2.24: Decomposition of net interest income changes between 2014 and 2019



Notes. The sample is composed by 194 Euro area banks. The unit of measure is the percentage change over the total.

Source: Boucinha & Burlon (2020)

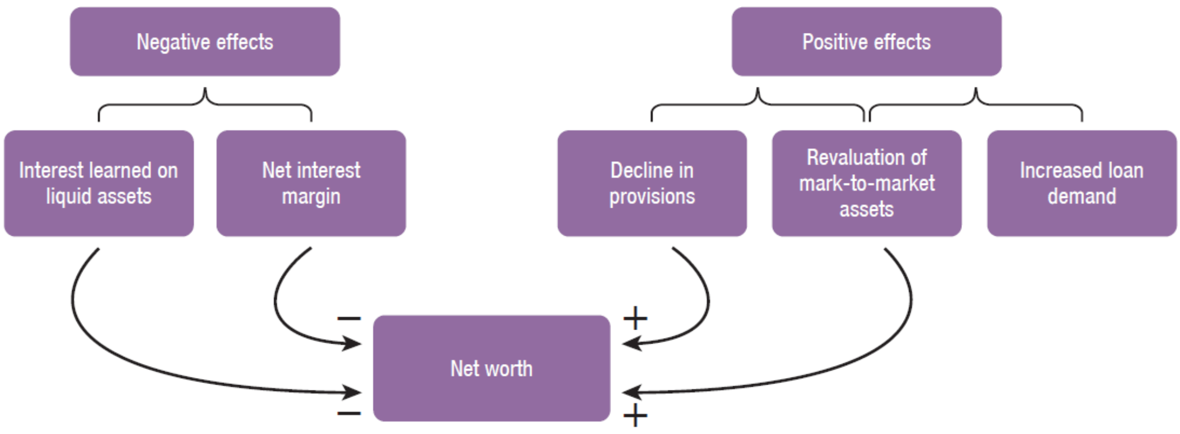
As depicted in Figure 2.24, the overall effect during NIRP period is a contraction of net interest income. The picture is, however, not complete if we are interested in the comprehensive impact of NIRP on bank profitability. We need indeed to discuss the implications on non-interest income sources and the role of the improved macroeconomic conditions due to the accommodative monetary policy.

- As for the non-interest income variable, policy rate cuts generate a positive revaluation of financial assets, as explained in the section about the financial markets channel. For banks, this translates in capital gains on mark-to-market securities they hold in their balance sheets.

- The improved macroeconomic outlook, instead, can be beneficial to bank profitability in different ways. First of all, it can stimulate the growth of credit demand, contributing to build the quantity effect illustrated in Figure 2.24. Moreover, the enhanced health of the broader economy can lead to better borrower creditworthiness. This is supported in a direct way also by the lower lending rates charged, that relieving the interests burden, contribute to a higher repayment capability of borrowers and so to an improved quality of loans. From the economic point of view, this higher quality translates in lower loan loss provisions.

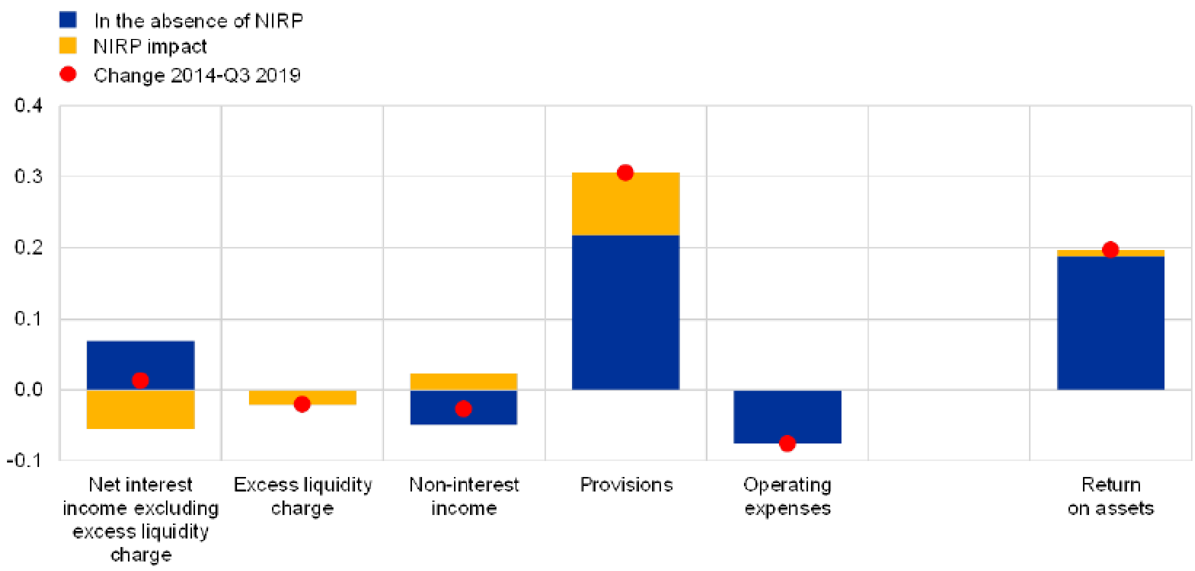
Figure 2.25 summarizes the variables affected by NIRP that contribute to the overall effect on profitability and, through retained earnings, also on net worth. Altavilla et al. (2019) and Boucinha & Burlon (2020) conclude that, taking into account all the contrasting forces, the comprehensive impact of NIRP on profitability is negligible, or at least there is no evidence of a negative effect so far. Figure 2.26 reports in detail the decomposition of the impact of NIRP on the different variables and shows how the overall effect of negative rates on a key profitability measure, such as ROA, is insignificant. We are referring, in particular, to the yellow components that represent the isolated contribution of NIRP, while the blue ones are the effects not due to the implementation of negative rates. The decomposition in yellow and blue components is obtained starting from the actual results between 2014 and 2019 and applying a counterfactual scenario with no NIRP.

Figure 2.25: Potential effects on bank profitability and net worth



Source: IMF (2021)

Figure 2.26: Changes in bank profitability between 2014 and 2019



Notes. The sample is composed by 194 Euro area banks. The unit of measure is the percentage change over the total. The NIRP impact is obtained through a dynamic BVAR model.

Source: Boucinha & Burlon (2020)

To conclude our analysis, it is important to highlight that a prolonged period of negative rates significantly increases the likelihood to see a deterioration of bank profitability. In fact, some positive effects, such as the capital gains due to asset revaluation, are transitory and concentrated close to rate cuts, while the contraction of interest margins is more persistent. Moreover, in the first years of NIRP, banks still benefitted from the higher interests on (still not matured) fixed-rate loans originated before policy rate cuts.

The eventual worsening of bank profitability would entail negative side effects also on bank net worth, due to lower retained earnings available as source of capitalisation. This situation, in presence of restricting regulatory constraints, may undermine the capability of low capitalised banks to extend credit, as described by Brunnermeier & Koby (2018) reversal rate. Some banks may react raising loan rates, in an attempt to sustain profitability restoring interest margins, but they would inevitably see hard times in facing competition. The issue of capitalisation is exacerbated also by the low valuations of banking sector stocks, with several commercial banks that, for example, trade at market to book ratios lower than one. These conditions discourage banks to tap capital markets to raise equity because this decision would lead to an important dilution of current shareholders holdings.

2.4. Interaction among NIRP and other monetary policy tools

We have already mentioned several times the existence of interactions and complementarities among NIRP and other monetary policy tools. In this paragraph, we describe in detail these interrelations and reciprocally enhancing effects, focusing on negative interest rate policy (NIRP) in combination with forward guidance (FG), asset purchase programs (APP) and targeted longer-term refinancing operations (TLTRO), with the Euro area as a reference for the analysis. For a summary of the following discussion, see the table by Rostagno et al. (2019) (Annex, Table A3).

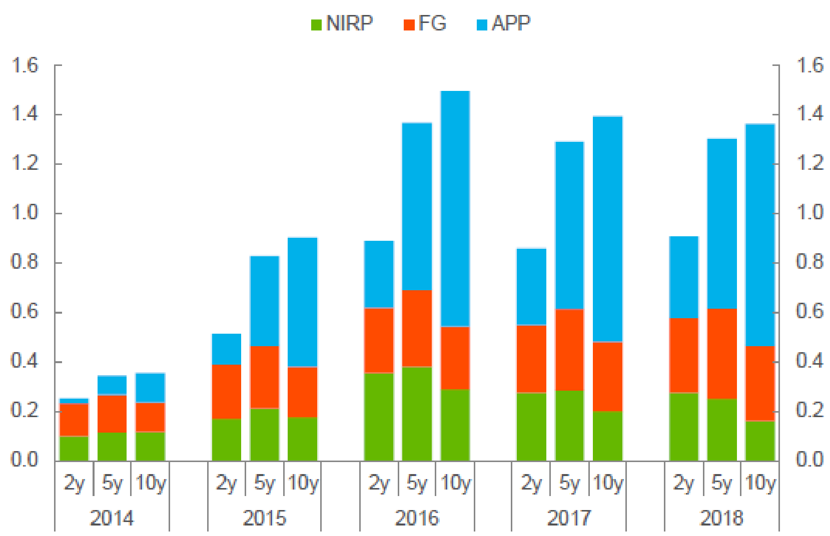
NIRP and forward guidance reinforce each other since they both work through the expectations channel to affect longer term rates. NIRP removes the non-negativity restriction for current and future expected short term rates, opening the space for more accommodative expectations including negative rates. Forward guidance, that has the specific aim to influence the expected path of policy rates, can enhance its effects thanks to NIRP. In fact, when negative rates are considered realistic in agents' expectations, the promise by central banks to keep very low rates or even reduce them is more compelling. In turn, forward guidance can reinforce NIRP to the extent that leaves the door open for even more negative rates or at least declares the expected persistency of negative rates. In this way, since agents do not see NIRP merely as a transitory phenomenon, they transmit the effects to forward curves (see, for example, Figure 2.5) and longer-term rates.

In addition, NIRP may represent not only a complement but also a substitute of forward guidance, in specific situations. The latter, indeed, relies on the credibility of the central bank to result effective and this credibility is not necessarily always at high levels. In these cases, NIRP is particularly precious because a rate cut is an observable action, less dependent on the concept of credibility (IMF, 2021). Of course, if the trust in the central bank is low, also the impact of NIRP would be probably weak, for example because of doubts about the persistency of the introduced negative rates.

Moving to the relationship among NIRP and asset purchase programs, it is possible to identify several channels of interaction. First of all, APPs have the objective to moderate longer-term rates and NIRP can reinforce the result through the expectations channel. Actually, the complementarity is even stronger: given that APPs lead to a rise of commercial banks reserves, the effect of NIRP, which imposes a charge on excess reserves, can be enhanced. In fact, as a consequence, individual banks, in search for yield, are incentivised to rebalance their portfolios towards longer-dated (and/or riskier) assets, so exerting further downward pressure on term premiums. We can find empirical evidence of this relationship looking at Table 2.3, reported in paragraph 2.2.2. The effect of the term factor on long-term yields (10Y maturity) is much stronger during NIRP (coefficient 7.928 vs 4.682), with also a p-value close to zero that leads to reject the assumption of a similar reaction in the two regimes taken into consideration. This happens because asset purchase programs produce an increase of reserves and, when these are charged negative rates, banks are incentivised to rebalance their assets towards longer-term securities, so enhancing the contraction of the term premium.

From the discussion so far, it is evident that NIRP, forward guidance and asset purchase programs have all a clear impact on medium-long term rates and they reinforce one another. For this reason, it can be interesting to have a look at their cumulative effects on the yield curve, which represents a key benchmark on the financial markets. Figure 2.27 depicts the results deriving from the counterfactual analysis by Rostagno et al. (2019), adapted to isolate the individual contribution of each one of the three UMP considered. We notice that the overall impact is particularly strong, as expected, on medium-long term maturities (5y and 10Y): in particular, from 2016 and 2018, the upward pressure on 5Y and 10Y Euro area sovereign yields would have been always greater than one percentage point, in absence of ECB's unconventional tools. This is an empirical clear confirmation of the effectiveness of non-standard policies to keep medium and long term rates under control.

Figure 2.27: Upward pressures on euro area sovereign yields in absence of ECB's UMP



Notes. Evolution of the upward pressures that euro area sovereign yields, at selected maturities would have experienced in absence of ECB's non-standard measures (percentage points). The chart illustrates the contribution of individual measures. The results are based on a BVAR.

Source: Rostagno et al. (2019)

The cooperation between NIRP and APPs to reduce long-term rates is probably the most evident complementarity, but not the only one: as we have already discussed, the increased reserves supply, caused by asset purchase programs, has played a key role in keeping short-term money market rates close to the deposit facility rate. In practice, it is thanks to the excess liquidity injected by APPs if cuts of the DFR had a direct and often almost one-to-one effect on short-term interbank rates.

In addition, NIRP and APPs have touchpoints also as concerns the banking system. The most immediate effect is strictly related to the above mentioned portfolio rebalancing activity, given that banks may also increase lending when involved in their search for yield.

Finally, NIRP has some contact points also with targeted longer-term refinancing operations. These are basically an extension of main refinancing operations, through which the central bank provides liquidity at much longer maturity, with the aim to spur lower lending rates and therefore stimulate a growth of loans demand. The second generation of TLTRO (TLTRO-II), starting in March 2016 has in particular benefitted from positive externalities with NIRP. In fact, the ECB established that commercial banks respecting the minimum thresholds in terms of net lending and loan growth had right to access funding from TLTRO at rates "*as low as the interest rate on the deposit facility*" (ECB Governing Council, March 2016). Since NIRP consists in a further reduction of the DFR below the ZLB, it contributes to safeguard lending margins: commercial banks typically squeeze net interest margins when they reduce lending rates to increase loan origination, but this negative force can be mitigated by the possibility to borrow funds at negative rates, thanks to the concurrent presence of TLTRO and NIRP.

2.5. Impact of NIRP on Inflation and Output

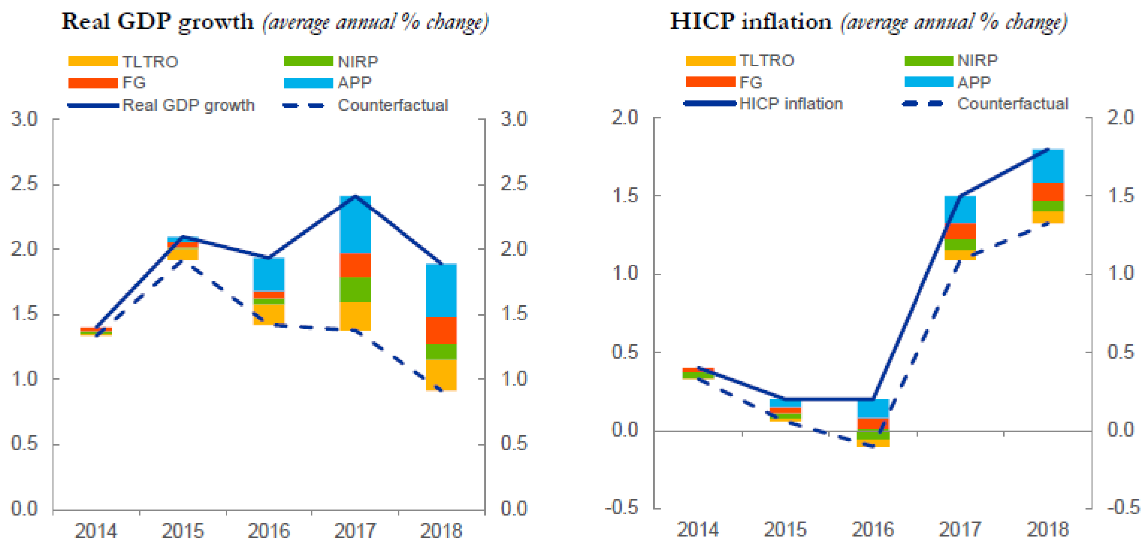
To conclude, it is fundamental to assess the impact of negative interest rates on output and inflation. Given the effectiveness of NIRP in easing financing conditions and the positive results in terms of transmission to financial markets, in particular as regards the yield curve, we can argue that the monetary policy tool under analysis has played a role in stimulating the economy as a whole.

However, the empirical evidence collected so far is limited because, as explained in previous discussions, the identification of the individual contribution of NIRP is complicated by the overlapping of several forces and the concurrent use of other monetary policy tools. If this was true in case of financial markets, the issue is even more pronounced as concerns slow-moving variables such as gross domestic product and inflation.

One precious and refined attempt to isolate the effects of NIRP is provided by the approach by Rostagno et al. (2019), described in paragraph 2.2.2, which focuses on the Euro area: the authors managed to decouple the contribution of the different non-standard monetary policies in terms of support given to the most relevant macroeconomic variables, namely output and inflation, represented by real GDP growth and HICP (harmonised index of consumer prices) inflation in their study. Since the methodology used relies on counterfactual analysis, two different paths are depicted in Figure 2.28: the actual values of real GDP growth and HICP inflation (blue solid lines, respectively in the left and in the right panel) compared against their corresponding counterfactual in absence of ECB unconventional policies (dashed blue lines). The actual results are always placed above the counterfactual ones, testifying the positive impact of UMPs we expected. The overall cumulated support given by non-standard tools to real GDP amounts to about 2.5% - 3%, from 2014 to 2018, while, over the same period, the average annual inflation would have been one third of a percentage point lower without the unconventional policies.

An aspect that deserves particular attention is the disaggregation of the contribution of each individual measure (coloured bars). APPs had the largest impact, in particular from 2016, on both inflation and output. However, NIRP, that is the main object of interest in our discussion, gave a significant support, especially considering the quite limited magnitude of DFR cuts. The contribution of negative interest rate policies as a standalone instrument is estimated in the order of one fifth or one sixth of the overall cumulated GDP growth due to UMPs, and a similar proportion is attributed to NIRP also as regards the impact on inflation.

Figure 2.28: Counterfactual output and inflation in absence of ECB's unconventional tools



Source: Rostagno et al. (2019)

Therefore, the empirical evidence provided by Rostagno et al. (2019) corroborates the argument that NIRP has been a positive experience so far, given its effective support to the whole economy. The study by Ulate (2019) also confirms the role of negative rates in stimulating the economy, even though the author finds a reduced effectiveness compared to rate cuts in positive territory. In particular, Ulate (2019) adopted a DSGE model on global data, using countries with low but positive rates as a control group, and he found that the presence of downward rigidity on deposit rates and the squeeze of bank profits can reduce the efficiency of monetary policy (the effectiveness is between 60% and 90% of the impact of same sized conventional rate cuts).

Finally, after having shown the main positive aspects of NIRP, in order to complete the assessment of this quite recent monetary policy tool, some warnings and concerns will be exposed in the next section, which focuses on possible other sides of the coin.

Chapter 3: Potential risks of unintended effects

The introduction of negative interest rate policies has effectively supported the economy, acting through both the financial markets channel and the banking sector. However, NIRP entails also potential side-effects that, as discussed talking about bank profitability, may emerge and enhance in particular in case of a prolonged period of negative rates.

The risk of build-up of financial vulnerabilities is actually something not peculiar of non-standard tools but it regards, more generally, low rates environments. On this point, Adrian & Liang (2018) argue that, in presence of financial frictions, accommodative monetary policies basically face an intertemporal trade-off between improving current financial conditions and potentially rise future financial vulnerabilities. The trade-off is particularly relevant at low rates and NIRP may, if anything, exacerbate the potential criticalities. For example, we have explained that negative rates are specifically effective in stimulating risk-taking, which can give, in principle, a positive contribution to the overall economy (e.g. through a higher loan provision). The problem is if and when this enhanced risk-taking attitude becomes excessive, creating in this way financial vulnerabilities that increase the threat of financial instability and the sensitivity of the whole economic system to adverse shocks. The goal of this section is not the definition of parameters and thresholds to judge as excessive or dangerous the evolution of certain variables, rather the assessment of the role of NIRP in shaping potential financial vulnerabilities, that may undermine the resilience of the system and may contribute to the rising and the aggravation of future crisis.

The financial vulnerabilities potentially fuelled by low rates are, in general, object of attention also when monitoring the side-effects of negative rates, even though we have already identified some peculiarities (e.g. a stronger threat for bank profitability in the long-term or the enhanced impact of negative nominal yields on risk attitude). Given this premise, the categorisation of financial vulnerabilities by Malovana et al. (2020), reported in Table A4 in annex, represents a valid reference for a comprehensive discussion of potential unintended effects. Overleverage, excessive credit growth and debt, risk mispricing, interconnectedness and illiquidity are all concepts that we will deal with in the following, even though, in line with Adrian & Liang (2018), we will present the main issues by means of a classification in the different sectors involved: asset markets, the banking sector, non-bank financial institutions, the non-financial sector.

Before entering in the details of this analysis, it is worth underlying the prominent role of regulatory authorities. After the Great Financial Crisis, regulation became stricter and stricter, with the aim of avoiding or, at least, reducing the likelihood of repetition of such a deep crisis that arose basically from the financial sector. In the Euro area, for example, we find macroprudential and microprudential policies put in place to guarantee the resilience and the soundness of the financial system[19]. The former address the safeguard from the build-up of systemic risk, through the implementation of actions and constraints to smoothen the financial cycle and to increase resilience. The latter focus on the safety of individual entities, that in the end contributes to the stability of the whole system. Nevertheless, even in presence of strict regulation and close monitoring of supervisory authorities, several financial vulnerabilities may still represent a serious threat.

3.1. Asset markets

We start our analysis of the unintended effects of negative rates from the financial markets. In general, rate cuts boost asset prices through both the reduction of current benchmark rates and the easing of expectations about future rates. This expectation channel is particularly enhanced by NIRP, leading to stronger effects on longer maturities. In addition, this two natural forces are reinforced by the enhanced risk taking attitude due to lower rates. In case of NIRP, several agents react to negative yields on liquid assets investing in longer-term and riskier securities, with the consequent reduction of term and risk premia. This portfolio rebalancing activity is moved by the willingness to search for yield of banks, institutional and retail investors, but also by forces of behavioural finance, such as loss aversion, that make negative nominal yields particularly undesirable. The aspect to monitor is that an excessive risk taking may produce risk mispricing that, once adverse shocks induce a repricing of compensation for risk, may remarkably amplify the corrections in financial markets.

[19] See Beyer et al. (2017) for a thorough discussion of the topic.

It is highly difficult to determine when asset prices become excessively high. Some indicators, such as price to earnings for the stock market, give an idea of the "temperature" of financial markets but the capability to detect asset bubbles is at the same time very limited.

In any case, a strong growth of asset prices should always be monitored, in particular because it may create dangerous weaknesses for the financial system when matched with other financial imbalances. For example, it is relevant the role of debt and leverage (stimulated by lower rates), as well as the level of interconnectedness of the system. In fact, if adverse shocks produce sharper declines when asset prices are at high levels compared to their fundamentals, the negative spillover is exacerbated by high levels of debt and excessive leverage of investors. These latter may be no more able to repay their liabilities given their reduced financial wealth. In this context, we highlight that a strong interconnection of the whole financial and economic system significantly increases the risk of systemic contagion after an adverse shock. To make an example, the common exposures of banks and institutional investors to the same riskier assets would intensively amplify the impact of periods of fire-selling, given that several financial institutions (in particular, the slower ones to feel the danger) may face huge losses, till the point of threatening the overall stability of the financial system.

It is not surprising that the problems described above are the same which generated and deepened the Great Financial Crisis. Despite the lessons learned and the undertaken countermeasures, the same issues must be closely monitored because they may be a realistic bad outcome of a prolonged period of negative rates.

3.2. Banking sector

Moving to the banking sector, the first issue, already mentioned, is the tightening of net interest margins, which results to be particularly severe under NIRP and with a flatter yield curve. This, in turn, may translate, in case of a prolonged period of negative rates, in a contraction of bank overall profitability, especially in the long-term when the positive effects of capital gains and lower loan loss provisions gradually vanish. The deterioration of profits entails lower retained earnings contributing to bank capitalisation. This mechanism is particularly relevant in case of high deposits banks, given that the limited reduction of funding costs negatively affects their margins. Heider et al. (2019) argue that, since high deposit banks struggle more to make profits, they tend to be more constrained by regulatory capital requirements. As a consequence, they generally react with an enhanced risk taking attitude, lending to more riskier borrowers. In fact, they cannot extend lending in a relevant way because of regulatory constraints, so they try to sustain profitability with high yield loans, while lending less than low deposit banks.

Table 3.1 depicts exactly the positive relationship between the proportion of deposits over total bank assets and the riskiness of borrowers receiving loans: row 1 (first 5 columns) shows that, during NIRP, there is a positive and statistically significant coefficient between the deposit ratio and the volatility of firms ROA, where this latter represents a measure of borrower riskiness.

Table 3.1: Bank deposit ratio and riskiness of borrowers

	$\ln(\sigma(ROA_i)^{5y})$						
Sample	2013 – 2015				2011 – 2015	2011 – 2015 non-euro-area borrowers,	
						euro-area lenders	non-euro-area lenders
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit ratio × After(06/2014)	0.017***	0.016***	0.018***	0.020***	0.020***	0.033**	0.009
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.014)	(0.020)
Deposit ratio × After(07/2012)					-0.007	-0.012	-0.009
					(0.004)	(0.010)	(0.012)
Bank FE	Y	Y	Y	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y	Y	Y	Y
Country FE	N	Y	N	N	N	N	N
Industry FE	N	Y	Y	N	N	N	N
Country-year FE	N	N	Y	Y	Y	Y	Y
Industry-year FE	N	N	N	Y	Y	Y	Y
N	1,576	1,576	1,576	1,576	2,490	542	666

Notes. The sample consists of all completed syndicated loans of both private and publicly listed firms *i* at date *t* granted by any euro-area lead arranger(s) *j*, from January 2013 to December 2015 in the first four columns and from January 2011 to December 2015 in the fifth and sixth column. The sample in the last column consists of all completed syndicated loans of both private and publicly listed firms *i* at date *t* granted by any non-euro-area lead arranger(s) *j* from January 2011 to December 2015. In the last two columns, we furthermore limit the sample to non-euro-area borrowers. The dependent variable is the logged five-year standard deviation of firm *i*'s return on assets (ROA, using P&L before tax) from year $t-5$ to $t-1$. In the first six columns, *Deposit ratio*$_j$ is the average ratio (in %) of deposits over total assets across all euro-area lead arrangers *j* in 2013. In the last column, *Deposit ratio*$_j$ is the average ratio (in %) of deposits over total assets across all non-euro-area lead arrangers *j* in 2013. *After*(06/2014)$_t$ is a dummy variable for the period from June 2014 onwards. *After*(07/2012)$_t$ is a dummy variable for the period from July 2012 onwards. Robust standard errors (clustered at the bank level) are in parentheses.

Source: Heider et al. (2019)

Lending to riskier borrowers can, in principle, be positive for the economy since it stimulates the activity of financially constrained firms, but it increases the sensitivity of bank assets to adverse economic shocks, given that these shocks affect riskier borrowers in a stronger way.

Another relevant criticality in the lending activity is linked to the balance sheet channel. Given that lower rates increase the collateral value of borrowers, banks are propense to extend more credit.

The problem is that this collateral value may result to be pumped by high asset valuations and, therefore, it may lead to an inadequate creditworthiness assessment and to an overall reduction of loan quality.

The increased risk-taking in response to the contraction of profitability involves not only the credit activity, but also the investments in securities. As already explained, banks react to negative rates on liquid assets with the so called "reaching for yield" behaviour. We have clarified the problem of investments in assets with compressed risk premia, while for banks it is very important to monitor also the risk of excessive maturity transformation. Investing in longer-term assets may induce illiquidity problems, that are indeed one of the main variables object of prudential regulations.

Summing up, the comprehensive riskiness of balance sheet assets may expose banks to relevant losses, again fuelled by the level of interconnection. We can indeed notice how it is common that the financial wealth of some borrowers (and so their creditworthiness) depends exactly on the same assets held by banks. It is therefore clear the augmented (through the impact of distressed repayment capability) effect of a sharp decline of these asset prices on banks net worth. As anticipated in the previous paragraph, a high level of leverage can then exacerbate the negative effects, because banks (but the same would be true for other overleveraged financial actors) would face troubles in servicing their liabilities, spreading the contagion. Focusing here on the banking sector, regulatory authorities have posed constraints on banks leverage through capital requirements, even though an extensive use of derivatives may still represent an issue. Moreover, the tendency to shift some assets off balance sheets, with the aim to respect capital requirements, may produce the side effect of a higher systemic risk, as we will explain below.

3.3. Non-bank financial institutions

The negative side effects of NIRP are not limited to banks, rather they involve several financial actors. We start the discussion from the so called shadow banking, the system of actors involved in the securitisation process. Since the prudential regulation is less strict than for the banking sector, this segment results to be riskier and more exposed to systemic contagion.

The 2008 crisis has forcefully shed light on this criticality, as well as on the relevance of collateral valuation and rating (the well-known case of subprime mortgages). In this context, it is clear the importance of monitoring potential vulnerabilities such as risk mispricing and excessive interconnectedness, obviously together with the level of debt and leverage that may act as a powerful catalyst of contagion transmission.

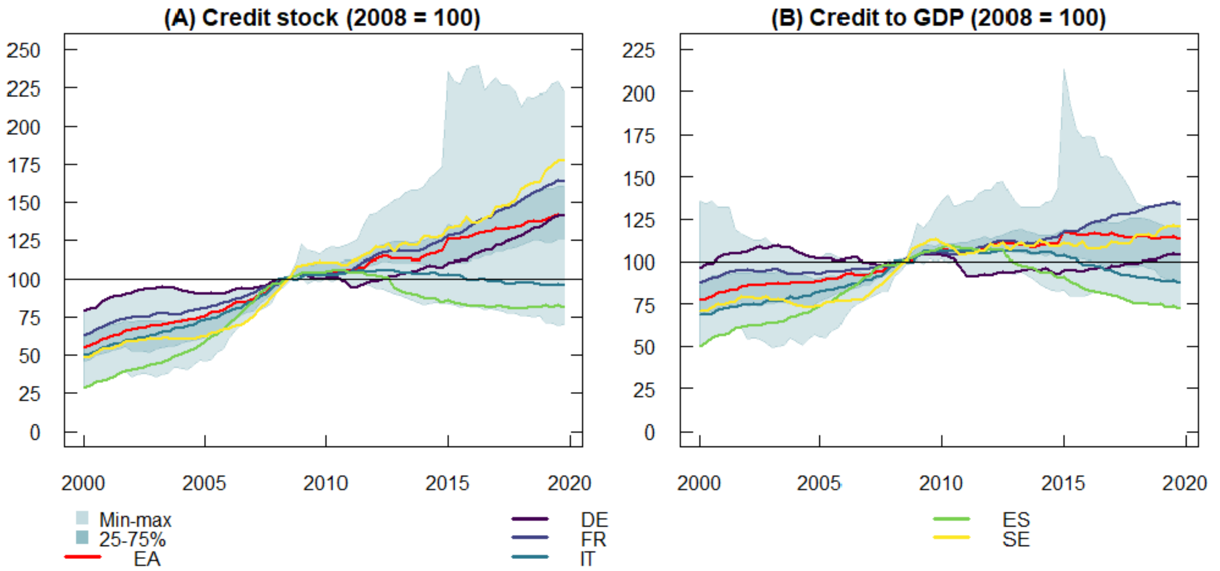
Moving to other actors of the financial landscape, the activity of institutional investors such as insurance companies and pension funds may be severely challenged by NIRP. In fact, given that nominal target returns often characterise these financial intermediaries, negative rates may influence their risk attitude and, more in general, their role as safe investment alternatives in the system, again increasing the level of interconnectedness.

3.4. Non-financial sector

Finally, we focus our attention on the impact of negative rates on households, non-financial corporations and governments. In general terms, lower rates spur credit growth, that sustains in the short-term the real economy but it also entails the build-up of debt. We can indeed observe, respectively in Figure 3.1 and 3.2, how, in some Euro area countries, the indebtedness of corporations and households has massively increased from 2008, in absolute terms (credit stock, left panels) and in some cases (e.g. Sweden and France) also in relative terms (credit to GDP, right panels).

As explained, high debt levels are a strong amplifier of the effects of adverse shocks and a catalyst in the transmission of contagion. In particular, in presence of high asset valuations and excessive interconnectedness, the mixture may result explosive.

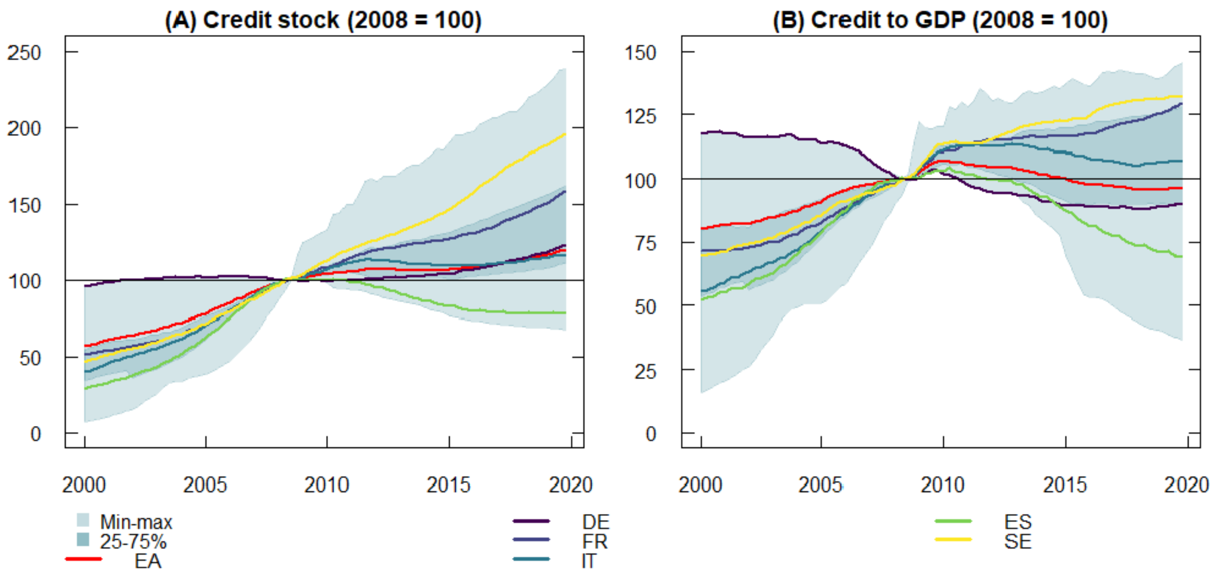
Figure 3.1: Indebtedness of non-financial corporations



Notes. BIS Statistics Warehouse – Credit Statistics. Credit from all sectors in the domestic currency; the base of the index equals the average for all four quarters of 2008. Countries in the sample: AT, BE, SW, CZ, DE, DK, ES, FI, FR, UK, GR, HU, IE, IT, NL, NO, PL, PT, SE.

Source: Malovana et al. (2020)

Figure 3.2: Indebtedness of households

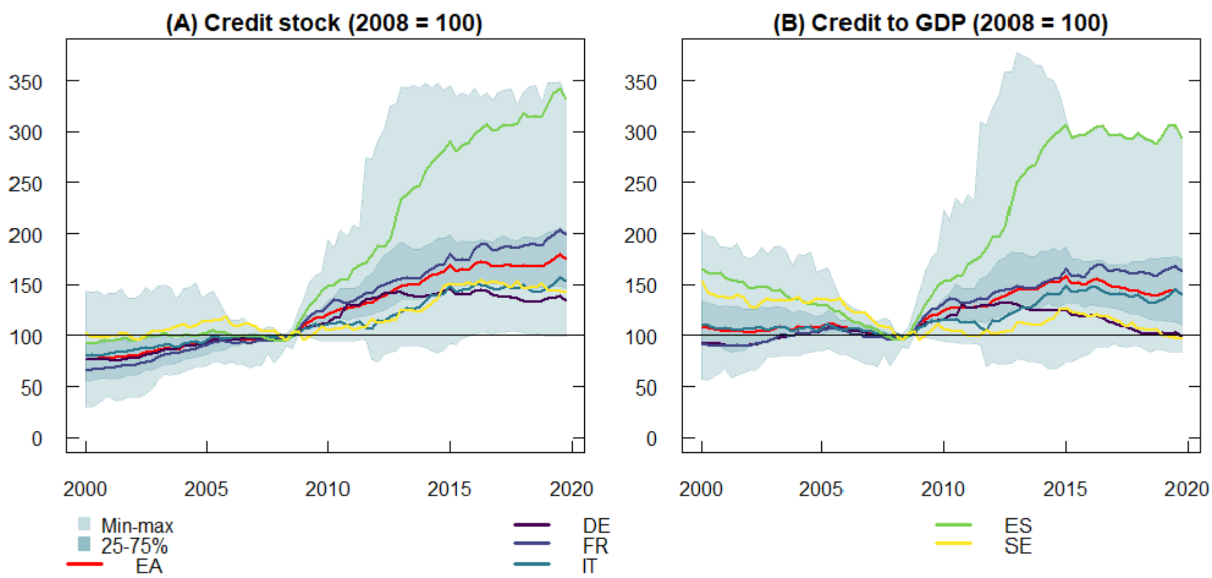


Notes. BIS Statistics Warehouse – Credit Statistics. Credit from all sectors in the domestic currency; the base of the index equals the average for all four quarters of 2008. Countries in the sample: AT, BE, SW, CZ, DE, DK, ES, FI, FR, UK, GR, HU, IE, IT, NL, NO, PL, PT, SE.

Source: Malovana et al. (2020)

Finally, we should remind that it is possible to reach a point of no return, i.e. a situation in which the "normalisation" of monetary policy would entail serious threats to financial stability. Tightening actions through the increase of policy rates, for example in answer to an expected high inflation, may have severe consequences when asset valuations are heavily sustained and reliant on monetary policy and the levels of debt are particularly high. This last aspect closely regards also the public sector, with massively indebted governments that are very sensitive to rate hikes. Figure 3.3 depicts the growth of Euro area governments debt from 2008, both in absolute (credit stock, left panel) and relative (credit to GDP, right panel) terms.

Figure 3.3: Government indebtedness



Notes. BIS Statistics Warehouse – Credit Statistics. Credit from all sectors in the domestic currency; the base of the index equals the average for all four quarters of 2008. Countries in the sample: AT, BE, SW, CZ, DE, DK, ES, FI, FR, UK, GR, HU, IE, IT, NL, NO, PL, PT, SE.

Source: Malovana et al. (2020)

Chapter 4: A SVAR model for the Euro area

This last section aims at investigating the empirical relationship between monetary policy and macroeconomic variables during the NIRP period in the Euro area. In fact, while the literature that documents the positive effects of negative rates on the financial markets and the banking sector is quite rich, the evidence regarding the impact of NIRP on output and inflation is rather scarce. The reference work for this topic is the counterfactual analysis by Rostagno et al. (2019), who found a significant contribution of NIRP to macroeconomic variables in the Euro area. In particular, negative rates account for about one fifth of the overall effects of unconventional monetary policies between 2014 and 2018, translating in a cumulated 0.5% increase of real GDP and a 0.07% rise of annual inflation due to NIRP.

The main research question we want to address is if the infringement of the zero lower bound entailed a significant change respect to the standard transmission mechanism of monetary policy shocks to macroeconomics variables. The easing of financing conditions and the stimulation of lending, discussed in section 2, typically support the economy in a relevant way, leading to the thesis that negative rates are likely beneficial for output and inflation (thesis corroborated by Rostagno et al. (2019)).

The goal of this section is to contribute to the literature, providing a not too complex baseline framework able to connect in a comprehensive model the evidence present in the literature, with the final aim to assess and confirm the robustness of the transmission mechanism of monetary policy shocks following the introduction of NIRP. The econometric tool employed for the declared objective is a Structural Vector Autoregressive model (SVAR), a quite common application in the literature. Behrendt (2017), Peersman (2011), Peersman & Smets (2001), Uhlig (2005) are the main references considered for the model presented below, even though some choices are customised for the specific research goal.

4.1. Model Specification

Structural VAR models are frequently used in empirical research because they deliver the identification and isolation of structural shocks. Compared to VAR models in reduced-form, the structural forms allow for explicit contemporaneous interactions between variables, as shown in the expression below.

$$B_0 * y_t = c + B_1 * y_{t-1} + B_2 * y_{t-2} + \cdots + B_p * y_{t-p} + \varepsilon_t \qquad (4.1)$$

This is the general expression of a SVAR of lag order *p*. The vector Y is the set of k endogenous variables considered in the model, c is a vector of k constants, B_i are k x k matrices. In particular, B_0 represents the contemporaneous relationships among the k variables and it is particularly important for the identification of the structural shocks $\varepsilon_{i,t}$, as detailed in the next paragraph (4.2).

The first step for the construction of the model is the definition of the variables of interest. The benchmarks considered are mainly Behrendt (2017) and Peersman (2011), even though we customise the model for our specific research goal. In fact, the cited papers focus their attention on the effects of unconventional monetary policies (not specifically NIRP) through bank lending, while we have already clarified the importance of both the financial markets and the banking sector channels in the transmission of negative rates.

Starting from macroeconomic variables, we proxy *Output* and *Prices* respectively with Industrial Production and the Harmonised Index of Consumer Prices (HICP) in the Euro area.

The EONIA rate (named *Short-term Rate* in the model) is the reference considered to derive policy rate shocks, given that this money market rate reflects closely monetary policy decisions. As explained in paragraph 2.2.1, it was typically aligned to the MRO rate, at least until the introduction of UMPs. Then, following the massive increase of liquidity reserves, it started to track instead the DFR rate, following it also in negative territory. This behaviour, evident for example in Figure 2.2, makes the EONIA rate a suitable candidate to represent the policy rate: before reaching the ZLB, the MRO rate was the main reference for policy decisions, while then the DFR rate became increasingly object of attention, in particular with the introduction of NIRP and the growth of excess reserves.

Moving to the next variable included in the model, it is already quite clear the relevance of Excess Reserves (henceforth *Reserves*), given their impact on the EONIA but also the complementary role they play with NIRP, reinforcing the effects of this monetary policy (see paragraph 2.4).

As anticipated, negative interest rate policies affect the economy through both the banking sector and the financial markets. In the model, the first channel is represented by means of the amount of Loans to non-financial corporations (*Lending*), while to take into account the financial markets channel, we include a long-term rate such as the *10Y Yield* on Euro area generic government bond.

Finally, an index of commodity prices is introduced as an exogenous variable (*Commodities*), following the suggestion by Sims (1992) to alleviate the so called price puzzle (the fact that in the VAR literature, prices sometimes react positively to monetary policy tightening, contrarily to textbook theory). A possible explanation is that interest rate rise may be a way to contrast coming inflationary pressures. If agents give this interpretation to the monetary policy decision, they revise upward their inflation expectations, generating a further increase of demand and inflation as answer to the fear of future higher prices. However, given that positive jumps in commodity prices typically anticipate inflationary pressures, the increase of consumer prices is, at least partially, explained by the rise in the commodities index, rather than attributed to the contractionary policy.

All the variables described are summarised in Table 4.1. As it is good practice in the literature, the model is expressed in log-levels, except for the interest rates in levels.

Table 4.1: Variables included in the SVAR model

Variable	Description	Source	Transformation
Output	Industrial Production index (2015=100)	Eurostat	Log-levels
Prices	HICP index (2015=100)	Eurostat	Log-levels
Reserves	Total Excess Reserves of credit institutions subject to minimum reserve requirements in the Euro area	ECB Statistical Data Warehouse	Log-levels
Short-term Rate	EONIA rate (percent per annum), average of observations through monthly period	ECB Statistical Data Warehouse	Levels
Lending	Loans to Euro area NFC reported by MFI (stock, in Millions of Euro)	ECB Statistical Data Warehouse	Indexed (2015=100), then expressed in Log-levels
10Y Yield	Euro area 10-year Government Benchmark bond yield (percent per annum)	ECB Statistical Data Warehouse	Levels
Commodities	Global Price Index of all Commodities (2015=100)	Fred	Log-levels

Note. All the variables are seasonally adjusted. In case the original time series is NSA, the command X-12-ARIMA is used for the seasonal adjustment. The grey background indicates the exogenous variable.

The full sample considered at the moment of dataset creation is 1999:01 – 2020:12, using monthly data. The focus is then on the subsample 2014:06 – 2020:02, period characterised by NIRP in the Euro area. The starting point is indeed the introduction of the negative DFR, while the end of the sample is taken before the huge impact of the pandemic induced lockdown. The presence of large outliers may distort the model estimation, in particular in a low-sized subsample.[20] The reduced number of observations is certainly a limitation to take into account during the discussion of the results, given that a weak data-to-parameters ratio may affect the robustness of the estimates. The sample 1999:01 – 2020:02 is instead used to test the adequacy of the model on a longer horizon. The summary statistics for the variables in both the samples are reported in Tables A5 and A6, in annex.

Finally, the phase of model specification is concluded identifying the optimal lag order for our VAR model. According to the standard Schwarz or Bayesian Information Criterion (BIC), which aims at maximising the log-likelihood while preserving the parsimony of the model, the optimal lag is one, consistently on both the samples analysed.

[20] Actually, even extending the horizon till the end of 2020, the results are not significantly different.

4.2. Estimation and Identification strategy

The structural form shown in expression 4.1 can be reconducted to the reduced form of the VAR, just pre-multiplying both sides of the equation by ${B_0}^{-1}$, the inverse of the contemporaneous matrix.

The reduced form VAR, with lag order equal to one and the variables previously described, has the following expression:

$$y_t = c_0 + A_1 * y_{t-1} + D_0 * x_t + D_1 * x_{t-1} + u_t \qquad (4.2)$$

where c_o is a vector of constants, A_1 is a k x k matrix, D_o and D_1 are k x 1 vectors multiplying the only exogenous variable x_t (*Commodities*).

This model is easily estimated, for example by ordinary least squares (OLS), and the residuals u_t are in this way built as difference between actual values and fitted values of y_t. We can notice that in the reduced form VAR there is no explicit contemporaneous interaction between the endogenous variables. However, focusing the attention on the residuals u_t, mutual correlation is not excluded. Formally, this corresponds to a variance - covariance matrix Σ that is not necessarily diagonal. In fact, while the structural shocks $\varepsilon_{i.t}$ are independent by construction, the residuals u_t can be seen also as $u_t = {B_0}^{-1} * \varepsilon_t$, passing from 4.1 to 4.2. As a consequence, being a linear combination of structural shocks, the residuals $u_{i,t}$ with $i = 1, \dots, k$ may be affected by the same structural shocks, explaining the possibility of mutual correlation. In the end, this implies that a structural shock, for example a monetary policy shock on the EONIA rate, may impact, also contemporaneously, several variables in the system.

Once the residuals u_t are obtained, we can exploit the correspondence between equations 4.1 and 4.2 and, especially, the relationship $u_t = {B_0}^{-1} * \varepsilon_t$ to derive the structural shocks. In particular, we are interested in the monetary shocks that can be interpreted as surprise changes in the policy rate, proxied by the EONIA rate.

However, some identifying restrictions on the matrix ${B_0}^{-1}$ are necessary to find univocally the structural shocks. In this work, we adopt a standard recursive identification, that means assuming a lower triangular ${B_0}^{-1}$ matrix. This kind of approach is also known as plain Cholesky model, since the ML (maximum likelihood) estimator of the matrix ${B_0}^{-1}$ results to be simply the Cholesky decomposition of the residuals covariance matrix Σ.

Setting the upper part of ${B_0}^{-1}$ equal to zero (as shown in expression 4.3) translates in imposing some restrictions on the contemporaneous impact of structural shocks on the different variables. For this reason, the methodology is very sensitive to the ordering of the endogenous variables in the vector Y and, in turn, in the vector ε. The selected Cholesky ordering is shown in expression 4.4 and it is motivated below.

$$
{B_0}^{-1} = \begin{bmatrix} a & 0 & 0 & 0 & 0 & 0 \\ b & c & 0 & 0 & 0 & 0 \\ d & e & f & 0 & 0 & 0 \\ g & h & i & l & 0 & 0 \\ m & n & o & p & q & 0 \\ r & s & t & u & v & z \end{bmatrix} \qquad (4.3)
$$

$$
Y = [Output,\ Prices,\ Reserves,\ Short\ term\ Rate,\ 10Y\ Yield,\ Lending] \qquad (4.4)
$$

Being the first variable in the vector Y, *Output* is affected contemporaneously only by *Output* structural shocks. *Prices*, instead, react simultaneously to both *Output* and *Prices* shocks.

Short-term Rate shocks (column 4 of the matrix ${B_0}^{-1}$), that are the main object of interest, do not impact immediately *Output*, *Prices* and *Reserves*, but only with a lag. Instead, they have a contemporaneous effect on *10Y Yield* and *Lending* that represent the transmission channels of monetary policy to the real economy.

Reserves are inserted before the *Short-term Rate* in the ordering because, as already explained, higher amounts of excess reserves can have a direct impact in reducing the EONIA rate.

Once defined the ordering of the variables, the model is estimated and evaluated. In fact, before entering in the analysis and discussion of the results, it is important to check if the model appropriately fits the data. This means, for example, investigating the proprieties of the residuals u_t. By construction, a "good" model should generate residuals that behave as a white noise, with zero mean and null autocorrelation. This is what we find for our model, on both the samples considered.

4.3. Results

After the estimation of the model, this can be exploited to study the relationships among the variables of interest. Impulse Response Functions (IRFs) are a common tool used for this aim. In particular, we are interested in the effects of monetary policy shocks (intended as surprise changes in the EONIA rate) on the economy, namely *Output* and *Prices*.

As anticipated, the main research question is if the infringement of the zero lower bound entailed a significant change respect to the standard transmission mechanism of monetary policy shocks to macroeconomics variables. For this reason, we focus the attention on the subsample representing the NIRP period and we adopt the SVAR model described in the previous paragraphs to generate the IRFs of *Output* and *Prices* to policy rate shocks. The results of a one standard deviation shock in the EONIA rate are reported in Figure 4.1. We notice that the reactions of *Output* and *Prices* to an easing monetary policy shock are coherent with standard theories: an unexpected decrease of the EONIA rate leads to a positive pressure on *Prices* and, with some lag, also to an improvement of *Output*.[21]

[21] The presence of $I(1)$ components (variables integrated of order one) in the model can lead to permanent changes in the IRFs of some variables after an impulse shock (Luetkepohl, 2011).

Figure 4.1: Impulse Response Functions, NIRP period

Note. The y axis of *Output* and *Prices* IRFs refers to the log version of the variables. The x axis covers a 60 months horizon, i.e. the 5 years following the shock. The light green 68% confidence interval is obtained by bootstrapping with 400 iterations.

Moreover, the results of the model highlight that the economy is reached passing through the expected transmission channels, i.e. easing financial markets conditions and stimulating the banking sector. Figure 4.2, indeed, shows that an expansionary surprise change of the *Short-term Rate* leads to a decrease of the *10Y Yield* and a rise of *Lending* to non-financial corporations[22].

[22] These results are in line with the empirical evidence in the literature, discussed in section 2.

Figure 4.2: Impulse Response Functions of transmission channels during NIRP

Note. The y axis of *Lending* IRF refers to the log version of the variable. The x axis covers a 60 months horizon, i.e. the 5 years following the shock. The light green 68% confidence interval is obtained by bootstrapping with 400 iterations.

4.4. Discussion

Summing up, the model seems to work well on the NIRP subsample, providing interesting confirmations of an unimpeded transmission of monetary policy to the real economy. A further positive element is that the model returns consistent results also considering a longer horizon (sample 1999:01 - 2020:02). You can see in Figure A1, in annex, that the medium long-term reaction of *Output* and *Prices* to policy rate shocks has a similar behaviour to the one observed for the NIRP period.

However, it is worth underlying that our SVAR model presents also relevant limitations and caveats, in particular as concerns its application on the NIRP subsample. First of all, as already mentioned, the reduced size of the sample threatens the robustness of parameters estimation and leads to quite large confidence intervals, as you can see in Figures 4.1 and 4.2. Moreover, the short period of time considered complicates the recognition of trend and cyclical components: for example, if a variable is declining as part of its cyclical behaviour and it does it for the entire (limited) span of time in the sample, the model may mistakenly interpret the situation as a downtrend characterising the variable by its nature. For this reason, we do not include explicit trend deterministic components in the baseline representation[23], "forcing" the model to explain eventual trends through the relationships among the variables interacting in the SVAR.

Notwithstanding the described limitations, the outcome of the model appears quite interesting: the impulse response functions testify that, even in presence of negative rates, the transmission of monetary policy follows standard dynamics. This represents an important finding that corroborates the results by Rostagno et al. (2019). In fact, as already argued, while the evidence regarding the effects of NIRP on the financial markets and the banking sector is quite extensive, the study of the link with macroeconomic variables is limited.

The counterfactual analysis by Rostagno et al. (2019) shed light on the significant support given by NIRP (and other UMPs) to real economy variables. Our econometric application provides, by means of a basic framework, a confirmation of the fact that, facing the ZLB, the ECB has successfully found significant additional room for manoeuvre moving in negative territory. Basically, the introduction of NIRP brought the possibility to carry on the traditional central bank activity of steering interest rates, without assisting to a disruption of the typical transmission mechanisms. This finding is in line with the estimations according to which the effective lower bound and the reversal rate have not been reached so far in the Euro area (Brunnermeier & Koby (2018), Rostagno et al. (2019)).

[23] Knowing it is a tricky decision, also due to the presence of trend stationary and non-stationary variables, we tested the model also with the inclusion of trend. This version of the SVAR behaves quite consistently on a longer horizon, while the results are more affected in case of the NIRP subsample, confirming the lower robustness.

In the end, we can argue that the quite intuitive structural model proposed in this section is able to provide confirmation of the effectiveness of monetary policy below zero. In particular, it allows to connect all the pieces in a simple framework. Starting from the steering of the policy rate, the economy is effectively reached passing through the expected channels, namely the financial markets and the banking sector.

A final comment is devoted to prospective for future research. The SVAR model discussed up to here has provided significant qualitative insights about the relationships between some of the key variables for the Euro area. It is instead still lacking as concerns the validity of quantitative results, mainly because of the limited number of observations that undermines the robustness of the estimates. If the period on negative rates prolongs over time and the available sample therefore increases in size, the proposed framework can represent a valid alternative among the benchmark models in the VAR literature stream. In fact, with the improvement of the data to parameter ratio and so of the robustness of the model, this can become an important tool also for quantitative evaluations about the effectiveness of negative rates.[24]

[24] The proposed SVAR model would represent a complementary alternative to the DSGE model by Ulate (2019), that found an efficiency of monetary policy in negative field between 60% and 90% of the magnitude of effects due to positive rate cuts.

Conclusion

The experience with NIRP can be considered positive so far. Negative rates effectively transmitted through the conventional channels, the financial markets and the banking sector, even though with some peculiarities. The infringement of the zero lower bound allowed central banks to remove the non-negativity constraint on current and future short-term rates, reshaping in this way agents' expectations in light of realistic more accommodative scenarios. Moreover, the spread of negative rates to a range of short-term and less risky assets stimulated the risk taking attitude of agents in search for yield, leading in this way to the compression of term and risk premia.

These two merits attributed to NIRP translate in a stronger than usual impact on longer-term rates, which are typically the most relevant metric for economic decisions such as investing. The appreciation of bonds and stocks favours confidence and wealth effects that boosts consumption and, by means of a higher collateral value, plays a role also in enhancing the balance sheet channel.

The reduction of bank funding costs leads to lower loan rates and, consequently, higher credit demand, even though the downward rigidity on households deposit rates creates some uncertainty on the level of pass-through of NIRP to lending rates. In addition to the already mentioned balance sheet channel, negative rates reinforce the bank lending channel as a consequence of the increased risk taking of banks. Finally, it is worth mentioning a new mechanism, the so called corporate channel, which features the rebalancing activity of firms from liquid (and charged) assets to fixed investments.

All these effects, combined with the complementary role of negative rates with other unconventional policies, lead to the conclusion that NIRP is likely beneficial for the economy. Counterfactual analysis have indeed shown a positive contribution of NIRP to inflation and output in the Euro area.

The SVAR model presented in this thesis confirms that the infringement of the ZLB has not induced a disruption of the standard transmission mechanism of monetary policy. This finding also corroborates the thesis that, in the Euro area, the effective lower bound and the reversal rate have been not reached so far.

When longer time series will be available, VAR models (including the SVAR framework illustrated in this thesis) could be applied also to complement the analysis with a robust and more precise quantitative assessment of the effects of NIRP on the economy.

Summing up, the empirical evidence shows that NIRP has proved to be a valid tool when searching for additional room of manoeuvre in terms of policy easing, and for this reason no central bank should a priori rule out this opportunity.

However, for sure, some issues and doubts still remain after some years of uninterrupted application of NIRP. Bank profitability has not significantly deteriorated so far, but the resilience of the banking sector to more prolonged periods of negative rates and tight interest margins is a variable to keep monitored. In particular, the existence of a downward rigidity on household deposit rates aggravates the compression of margins and poses a limitation to the depth that can be reached in negative territory before seeing an impediment of the pass-through.

We know that bank profits have also a role in sustaining net worth through retained earnings, so the capability of banks to compensate the reduced NIM (e.g. increasing the relative weight of fees and commissions income[25]) is relevant for the functioning of the whole banking sector channel, which is subject to strict capital requirements.

Linked to these considerations, it also appears quite clear the attention that central banks should pay to the location of the reversal rate. This, together with the effective lower bound, represents the new reference lower bound for nominal rates. A potential complication for policymakers is that, while the ZLB was a naturally and univocally identified limit, the "new" constraints can only be estimated. For this reason, it is definitely evident the importance of suitable refined theoretical frameworks able to provide reliable estimates in this field.

In addition to the potential problem regarding bank profitability, the threat of build-up of financial vulnerabilities is another material issue that central banks should account for in the cost side of the equation. We should indeed remark how the assessment of a monetary policy

[25] The new environment of ultra-low and negative rates poses a serious challenge for commercial banks, which see a significant deterioration of interest margins. This leads, as a possible reaction, to a gradual transformation of their business model towards a more service oriented one, so that the reliance on interest bearing activities can be reduced, in favour of fees and commissions not strictly dependent on the interest rates level.

must always consider and weigh both positive and negative effects, in the short-term but also looking at potential future consequences.

An additional matter, still not mentioned but quite popular in recent debates, regards the possible transition to central bank digital currency (CBDC). We have highlighted that NIRP owes its effectiveness to the concept of effective lower bound, which ultimately is based on the non-negligible cost of holding cash. The introduction of CBDC, without adequate support measures, may seriously undermine the sustainability of negative rates environments. The natural question that arises is, indeed, why someone should deposit money and being charged a negative rate if digital currency has no storage costs. The possibility to hold illimited quantities of digital currency at a cash-like zero-remuneration would imply that no financial instrument could yield a negative rate, otherwise it would be simply substituted with CBDC. This evidently means that NIRP would make no sense under these conditions. For this reason, considering that rates are expected to remain negative for a while or, in any case, that negative rates will likely be a realistic scenario in the future, the discussion about CBDC has focused also on its coexistence with NIRP. A possible identified solution is a two-tier remuneration system for CBDC (Bindseil & Panetta 2020). Below a certain holding threshold, CBDC can conserve cash-like properties, while higher amounts would be taxed in order to disincentivise its use as a large scale store of value.[26] In this way, the retail payment function of money is preserved, while also leaving space for the application of NIRP under a standard functioning of the monetary policy transmission mechanism.

In conclusion, the experience suggests that NIRP can be a useful monetary policy which deserves to be part of central banks toolkit, even though the concerns about potential side effects and the challenges for policymakers do not lack.

[26] The quantity for the threshold can be identified as enough to guarantee the use of CBDC for retail payments, as a perfect substitute of banknotes.

References

- Adrian, T. & N. Liang (2018), "Monetary Policy, Financial Conditions, and Financial Stability", *International Journal of Central Banking*, International Journal of Central Banking, vol. 14(1), pages 73-131, January.

- Albertazzi, U., F. Barbiero, D. Marques-Ibanez, A. Popov, C. Rodriguez D'Acri and T. Vlassopoulos, "Monetary policy and bank stability: the analytical toolbox reviewed", *Working Paper Series*, No 2377, ECB, February 2020.

- Altavilla C., D. Giannone and M. Lenza (2014), "The financial and macroeconomic effects of OMT announcements", *ECB Working Paper Series 1707, August 2014.*

- Altavilla, C., L. Burlon, M. Giannetti, and S. Holton (2019), "Is There a Zero Lower Bound? The Effects of Negative Policy Rates on Banks and Firms." *ECB Working Paper 2289*, European Central Bank, Frankfurt am Main

- Altavilla, C., M. Boucinha and J. L. Peydró (2018), "Monetary policy and bank profitability in a low interest rate environment". *Economic Policy*, *33*(96), 531-586.

- Amato, J. (2005), "The role of the natural rate of interest in monetary policy", *BIS Working Papers 171*, Bank for International Settlements.

- Arteta, C., M. A. Kose and T. Taskin (2016), "Negative interest rate policies: Sources and implications", *Policy Research Working Paper* 7791*,* The World Bank.

- Bech, M. L., and A. Malkhozov (2016), "How Have Central Banks Implemented Negative Policy Rates?" *BIS Quarterly Review* (March): 31–44.

- Behrendt, S. (2017), "Unconventional Monetary Policy effects on bank lending in the Euro area", *Jena Economic Research Papers 2017 – 002.*

- Bernanke, B. S. and A. S. Blinder (1988), "Credit, Money, and Aggregate Demand", *NBER Working Papers 2534.*

- Beyer, A., G. Nicoletti, N. Papadopoulou, P. Papsdorf, G. Rünstler, C. Schwarz, J. Sousa, O. Vergote (May 2017), "The transmission channels of monetary, macro and microprudential policies and their interrelations*", ECB Occasional Paper Series No. 191*

- Bindseil, U. and F. Panetta (2020), "Central bank digital currency remuneration in a world with low or negative nominal interest rates", VoxEU 05/10/2020

- Bottero, M., M. C. Minoiu, J. L. Peydró, A. Polo, M. A. F. Presbitero, and E. Sette (2019), "Negative monetary policy rates and portfolio rebalancing: Evidence from credit register data", *IMF Working Paper No. 19/44.*

- Boucinha, M., and L. Burlon (2020), "Negative rates and the transmission of monetary policy", *ECB Economic Bulletin Articles, 3/2020.*

- Brandao-Marques, L., M. Casiraghi, G. Gelos, G. Kamber and R. Meeks (2021), "Negative Interest Rates: taking stock of the experience so far", *IMF Departmental Papers / Policy Papers* 2021/003*,* International Monetary Fund.

- Bräuning, F., and B. Wu (2017), "ECB monetary policy transmission during normal and negative interest rate periods", *available at SSRN 2940553.*

- Brunnermeier, M. K. and Y. Koby (2018), "The reversal interest rate", *NBER Working papers* 25406.

- Christensen, J. H. E. (2019), "Yield Curve Responses to Introducing Negative Policy Rates." FRBSF Economic Letter 2019–27, Federal Reserve Bank of San Francisco, San Francisco, CA.

- Dynan, K. E., J. Skinner, and S. P. Zeldes (2004), "Do the Rich Save More?", *Journal of Political Economy*, 112(2):397–444.

- ECB, "Financial stability review", November 2020.

- Eisenschmidt, J., and F. Smets (2019), "Negative Interest Rates: Lessons from the Euro Area," *Monetary Policy and Financial Stability: Transmission Mechanisms and Policy Implications*, edited by A. Aguirre, M. Brunnermeier and D. Saravia. Santiago, Chile: Central Bank of Chile.

- Ferrari, M., J. Kearns, and A. Schrimpf (2017), “Monetary policy’s rising FX impact in the era of ultra-low rates”, *BIS Working Paper*, No 626.

- Gilchrist S. and E. Zakrajšek (1995), "The importance of credit for macroeconomic activity: identification through heterogeneity”, Federal Reserve Bank of Boston, vol. 39, pages 129-173.

- Greenwald B. C. and J. E. Stiglitz (1993), "Financial Market Imperfections and Business Cycles”, *The Quarterly Journal of Economics,* Oxford University Press, vol. 108(1), pages 77-114.

- Grisse, C., S. Krogstrup, and S. Schumacher (2017), “Lower-Bound Beliefs and Long-Term Interest Rates.” *International Journal of Central Banking* 13 (3): 165–202.

- Hannoun, Herve (2015), “Ultra-low negative interest rates: what they mean for financial stability and growth” Speech BIS.

- Heider, F., F. Saidi, and G. Schepens (2019), “Life below Zero: bank lending under Negative Policy Rates" *Review of Financial Studies*.

- Heider, F., F. Saidi, and G. Schepens (2021), “Banks and negative interest rates", *Annual Review of Financial Economics*.

- Hicks, J. R. (1937), “Mr. Keynes and the ‘Classics’: A Suggested Interpretation.” *Econometrica* 5 (2): 147–59.

- Holston, K., T. Laubach, and J. C. Williams (2016), “Measuring the Natural Rate of Interest: international trends and determinants” *Journal of International Economics*, vol. 108: 59-71.

- Juselius, M., C. Borio, P. Disyatat, and M. Drehmann (2016), “Monetary Policy, the Financial Cycle and Ultralow Interest Rates.” *International Journal of Central Banking,* 13 (3):55–89.

- Klein, M. (2020), “Implications of negative interest rates for the net interest margin and lending of euro area banks”, *Deutsche Bundesbank Discussion Paper No. 10/2020*

- Lane, P. R. (2019), “The International Transmission of Monetary Policy.” European Central Bank, Frankfurt am Main.

- Lane, P.R. (2020), “The monetary policy toolbox: evidence from the euro area”, keynote speech at the 2020 US Monetary Policy Forum, 21 February 2020.

- Laubach, T., and J. C. Williams (2003), “Measuring the Natural Rate of Interest.” *Review of Economics and Statistics* 85, no. 4: 1063–70.

- Lucchetti, R. and S. Schreiber (2018), "The SVAR addon for Gretl", *Gretl working papers 5*, Università Politecnica delle Marche (I), Dipartimento di Scienze Economiche e Sociali.

- Luetkepohl, H. (2011), “Vector autoregressive models”, *EUI Working Papers ECO 2011/30.*

- Malovana, S., J. Bajzik, D. Ehrenbergerova and J. Janku, (2020), "A prolonged period of low interest rates: unintended consequences" *Research and Policy Notes 2020/02*, Czech National Bank.

- Peersman, G. (2011), “Macroeconomic effects of Unconventional Monetary Policy in the Euro area”, *Working Paper Series 1397, European Central Bank.*

- Peersman, G. and F. Smets (2001), “The monetary transmission mechanism in the Euro area: more evidence from VAR analysis”, W*orking Paper Series 0091, European Central Bank.*

- Rachel, L., and L. Summers (2019), “On Secular Stagnation in the Industrialized World”, *NBER Working Paper No. w26198*.

- Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, A. S. Guilhem and J. Yiangou (2019), “A Tale of Two Decades: The ECB's Monetary Policy at 20”, *ECB Working Paper No. 2346*.

- Schmelzing, P. (2020), “Eight centuries of global real interest rates, R-G, and the ‘suprasecular decline’, 1311-2018”, *Bank of England Staff Working Paper, No. 845.*

- Schnabel, I. (2020), “Going negative: the ECB’s experience” Speech Roundtable on Monetary Policy, Low Interest Rates and Risk Taking at the 35th Congress of the European Economic Association.
- Sims, C. (1992), “Interpreting the macro-economic time series facts: the effects of monetary policy”, *European Economic Review*, 36, p 975-1011.
- Swanson, E. (2016), “Measuring the Effects of Unconventional Monetary Policy on Asset Prices”, University of California, Irvine.
- Tenreyro, S. (2021), “Let’s talk about negative rates” Speech at the UWE Bristol webinar given by Silvana Tenreyro, External Member of the Monetary Policy Committee, Bank of England.
- Uhlig, H. (2005), “What are the effects of monetary policy on output? Results from an agnostic identification procedure”, *Journal of Monetary Economics*, 52(2): 381-419.
- Ulate, M. (2019), “Going negative at the zero lower bound: the effects of negative nominal interest rates”, Federal Reserve Bank of San Francisco *Working Paper 2019-21*.
- Van Els, P., A. Locarno, B. Mojon and J. Morgan (2003), “New macroeconomic evidence on monetary policy transmission in the Euro area”, *Journal of the European Economic Association*, MIT press, vol. 1(2-3), pages 720-730, 04/05.
- Vlieghe, G. (January 2016), “Debt, Demographics and the Distribution of Income: New challenges for monetary policy”, speech given at the London School of Economics.
- Vlieghe, G. (May 2016), “Monetary policy expectations and long-term interest rates”, speech given at the London School of Economics.
- Wicksell, K. (1898), “Interest and Prices” *(indirect source)*

Annex - Tables

Table A 1: Events considered in the econometric approach by Arteta et al. (2016)

Central Bank (policy rate)	Date	Rate	Complementary Policies Announced
European Central Bank *(Overnight deposit facility rate)*	June-2014	-0.10	Targeted Longer-Term Refinancing Operations program with 2-year maturity. Announced preparations for an Asset Backed Securities Purchase Program
	September-2014	-0.20	Asset Backed Securities Purchase Program initiated
	December-2015	-0.30	6-month extension of asset purchase programs. Expanded pool of available assets for purchase, no increase in monthly amount
	March-2016	-0.40	Expanded size of Quantitative Easing program from €60 billion to €80 billion per month until March 2017, added non-financial corporate bonds to list of assets elibible for purchase, new Targeted Longer-term Refinance Operations program with four year maturity
Riksbank *(One week repo rate)*	February-2015	-0.10	Forward guidance, SEK 10 billion of government bond purchases
	March-2015	-0.25	Expanded bond purchases to SEK 30 billion
	July-2015	-0.35	Expanded bond purchases to SEK 75 billion
	February-2016	-0.50	Reinvested maturing bonds and coupons from QE program
Danmarks Nationalbank *(One week certificate of deposit rate)*	July-2012	-0.20	
	September-2014	-0.05	
	January-2015	-0.20	
	January-2015	-0.35	
	January-2015	-0.50	Suspension of new bond issuance
	February-2015	-0.75	
Swiss National Bank *(Overnight sight deposit rate)*	December-2014	-0.25	Minimum exchange rate reaffirmed
	January-2015	-0.75	Franc floor abandoned as overall "overvaluation has decreased," if necessary promises currency intervention in the future
Bank of Japan *(Current account deposit rate)*	January-2016	-0.10	No changes to existing Qualitative and Quantitative Easing program

Source: Arteta et al. (2016)

Table A 2: Response of more exposed relative to less exposed banks

	Paper	Identification strategy	Response of more exposed banks relative to less exposed		
			Loan price	Loan volume	Loan risk
Euro Area	Arce et al 2018	Self-reported NII impact		Similar corporate lending	Similar corporate loan standards, lower risk tolerance and risk-weighted assets
	Altavilla, Boucinha, Holton & Ongena 2018	Self-reported NII impact		More corporate lending	
	Amzallag et al 2019 (Italy)	Overnight deposits	Higher fixed mortgage rates (¼ of total) but similar floating rates		
	Bittner et al 2020 (Germany & Portugal)	Deposits		Mixed results for corporate lending	Mixed results, but more credit to new risky firms in Germany
	Bottero et al 2019 (Italy)	Interbank loans & securities	Lower corporate loan rates	More corporate lending	Bigger rise in lending for risky firms
	Bubeck et al 2020	Deposits		Increase securities holdings; mixed evidence on syndicated loan volumes	Buy riskier securities; increase syndicated lending for riskier borrowers
	Demiralp et al 2019	Deposits and reserves		More household and corporate lending for high deposit banks; similar private securities holdings	
	Grandi & Guille 2020 (France)	Deposits		More lending, especially to corporates; increase debt securities holdings	
	Heider et al 2019	Deposits		Less syndicated lending	Increase in average borrower risk
	Klein 2020	Impact of lower NIM		Usual hit to lending vanishes under NIRP	
	Tan 2019	Deposits	Lower mortgage spreads (limited evidence)	More lending (though effect dissipates), driven by mortgages, similar corporate lending	
Sweden	Eggertsson et al 2019	Deposits	Less mortgage rate pass-through	Less household lending	
Denmark	Adolfsen & Spange 2020	Deposits	Similar pass-through to households & corporates (but slower than normal)	Stronger or similar lending to households & corporates (depending on specification)	
Switzerland	Basten & Mariathasan 2018	Reserves	Higher mortgage rates	Increase in share of loan assets (both uncollateralised loans and mortgages)	Higher risk-weighted asset share
	Schelling & Towbin 2020	Deposits and reserves	Lower corporate loan spreads, lower or similar mortgage spreads	More corporate lending	More risk in corporate lending (across various dimensions)
Japan	Hong & Kandrac 2018	Equity price response to NIRP announcement		More lending	Higher loan portfolio yield, interpreted as higher risk borrowers, and longer loan maturities

Notes. In green, studies that found more accommodative lending conditions in case of more exposed banks.
In grey, studies that found not significant differences among more and less exposed banks.
In red, studies that found more contractionary lending conditions in case of more exposed banks.
Source: Tenreyro (2021)

Table A 3: Complementarities between monetary policy instruments

FROM \ TO	NIRP	FG	APP	TLTRO
NIRP	1.1 Empowered rate cut effect on rate expectations (removes their typical upward skew) and term premium (Gesell tax effect)	1.2 Signals a potential future rate cut, which generates curve inversion and downside pressure on lending rates	1.3 Reinforces impact of APP on term premium through the Gesell tax effect	1.4 Reinforces incentive scheme: stronger loan origination entitles banks to negative borrowing rate
FG	2.1 Contains potential term premium volatility created by larger future rate uncertainty (open possibility to increase or cut rates in future)	2.2 Controls the front-end of the forward curve by pricing out expected rate paths inconsistent with the central bank's language	2.3 Anchors the short-end of the curve to ensure it doesn't back up prematurely as APP stimulates the economy	2.4 Together with NIRP, keeps the intermediate segments of the risk free curve used by banks to price loans at low levels, thus stimulating loan demand
APP	3.1 Extra liquidity contributes to keeping overnight rate at the DFR. Contains potential term premium volatility created by larger future rate uncertainty (open possibility to increase or cut rates in future).	3.2 Extra liquidity makes the overnight rate indirectly controllable even if FG applies to DFR. Strengthens signal of accommodative stance for a long period of time	3.3 Extracts duration risk and compresses term premium directly through vast array of assets	3.4 Favours a decrease in the banks' return on bond holdings relative to the return on loan creation. Generates capital gains for banks and frees up balance sheet capacity that banks can redeploy to commercial loans under TLTRO
TLTRO	4.1 Exempts borrowed funds from NIRP tax on reserves	4.2 Strengthens signal of low rates for longer through a fixed borrowing rate	4.3 Favours increase in banks' return on loan creation relative to bond holdings	4.4 Squeezes intermediation wedge by compressing funding costs while preserving lending margins

Source: Rostagno et al. (2019)

Table A 4: Financial vulnerabilities potentially caused by low interest rates

Broad Category	Subcategory
Excessive credit growth and leverage	1. Overindebtedness and excessive debt service burdens of non-financial private sector 2. Excessive leverage of banks/low capitalization in relation to assets 3. Excessive securitization/rapid increase in banks' off-balance sheets 4. Regulatory (capital) arbitrage and leakages 5. Excessive leverage of non-bank financial institutions 6. Use of derivatives to mimic leverage
Mispriced risk	7. Deteriorating underwriting standards 8. Changes in portfolio quality 9. Compressed risk premiums on credit 10. Compressed risk premiums in various asset classes (equities, bonds, real estate) 11. Compressed term premiums 12. Undervalued risk parameters used to calculate regulatory capital requirements
Excessive maturity mismatch and market illiquidity	13. Excessive use of short-term or floating rate debt by non-financial sector 14. Excessive lengthening of asset maturities 15. Lower liquidity and solvency of insurance companies and pension funds
Misaligned incentives and moral hazard	16. Moral hazard of high deposit banks with lower equity 17. Moral hazard of friendly corporate governance 18. Excessive size of financial institutions bearing critical functions (too big to fail)
High interconnectedness and exposure concentration	19. Rapid increase in common asset holdings/highly correlated risks in balance sheets 20. Higher interconnectedness of financial systems 21. Excessive size of central counterparties, higher risk-taking and inadequate risk management 22. Shift from banking-based financial system toward capital markets

Source: Malovana et al. (2020)

Table A 5: Summary statistics, SVAR model sample 2014:06 - 2020:02

Variable	Obs.	Mean	Std Dev	Min	Max
Output	71	4.6287	0.028	4.5685	4.6821
Prices	71	4.6236	0.0198	4.5977	4.6582
Reserves	71	13.235	0.9514	11.309	14.229
Short-term Rate	71	-0.2638	0.1671	-0.4642	0.2539
Lending	71	4.6149	0.0149	4.5947	4.6483
10Y Yield	71	1.1445	0.5112	0.0478	2.6103
Commodities	71	4.7666	0.1453	4.4423	5.1277

Note. The reported values refer to the already transformed variables (e.g. expressed in log-levels). The grey background indicates the exogenous variable.

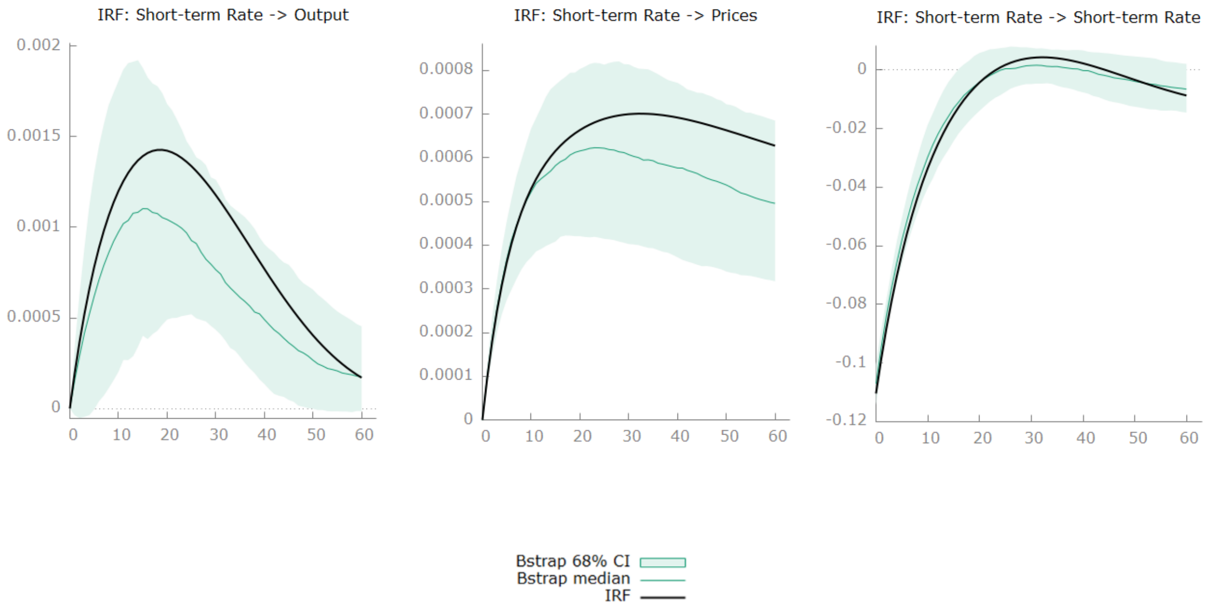
Table A 6: Summary statistics, SVAR model sample 1999:01 - 2020:02

Variable	Obs.	Mean	Std Dev	Min	Max
Output	254	4.5933	0.0501	4.4625	4.7014
Prices	254	4.5058	0.108	4.3005	4.6582
Reserves	254	9.0593	3.0565	6.2846	14.229
Short-term Rate	254	1.5298	1.6929	-0.4642	5.0642
Lending	254	4.4831	0.2225	3.9632	4.7267
10Y Yield	254	3.3096	1.5131	0.0478	5.6985
Commodities	254	4.655	0.4085	3.7395	5.2797

Note. The reported values refer to the already transformed variables (e.g. expressed in log-levels). The grey background indicates the exogenous variable.

Annex – Figures

Figure A 1: Impulse Response Functions, sample 1999:01 2020:02



Note. The y axis of *Output* and *Prices* IRFs refers to the log version of the variables. The x axis covers a 60 months horizon, i.e. the 5 years following the shock. The light green 68% confidence interval is obtained by bootstrapping with 400 iterations.

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