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Abstract

This paper surveys studies on the impact of central bank negative interest rate policies (NIRP). It reviews recent research on the effects of NIRP on financial markets, banks, households, firms, and the macroeconomy. Overall, policy rate cuts when interest rates are negative propagate along the yield curve, with the first policy cut below zero contributing significantly to the fall in longer-term yields. Lending and deposit rates also decrease following the adoption of NIRP. Based on the experience so far, bank lending volumes have risen, and bank profits have not significantly deteriorated, although there is considerable heterogeneity in the effects. The impact of NIRP on inflation and output appears to be comparable to that of conventional interest rate cuts.

JEL Classification: E43, E52, G21, G22, G23

Keywords: Negative Interest Rates, monetary policy, bank lending, Bank profitability, nonbank financial institutions

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1. INTRODUCTION

Negative nominal interest rates are often a cause for disquiet, even among economists. A claim with a negative nominal rate carries a promise to return to the buyer less, in terms of currency units, than she pays for it. In such a transaction, the usual roles of 'lender' and 'borrower' are reversed. This situation appears especially peculiar when physical cash offers a familiar alternative store of value that is technologically constrained to pay a zero nominal return. But the apparently paradoxical nature of negative nominal interest rates has not prevented them from emerging as a leading monetary policy tool.

Negative interest rates as a policy tool are a recent innovation. The first time a main central bank policy rate entered negative territory was in Denmark, in 2012. Since then, the European Central Bank (ECB) and central banks in Japan, Sweden, and Switzerland have also used a negative interest rate policy or NIRP (see Table 1). They did so when the room for easing policy by cutting rates in positive territory had been exhausted, and often in concert with other 'unconventional' monetary policy measures. To date, the Danish and Swiss central banks have gone further than any other with NIRP, setting rates as low as -75 basis points.

Central banks that employ NIRP levy a charge on the holders of settlement balances (central bank 'current accounts' or 'reserves').[1] In practice, access to standing facilities at the central bank is usually limited to commercial banks and other financial institutions. But NIRP does not mean rates are negative only for those with accounts at the central bank. The interest rates that central banks set for settlement balances influence money market rates and the yields on financial assets, especially on closely-substitutable instruments, through arbitrage relations.

Central banks' relative lack of experience with NIRP has led them to proceed cautiously. Its introduction was accompanied by questions including how transmission of policy to key funding and lending rates might differ from that of interest rate changes in positive territory, and the existence and nature of counterproductive effects from cash hoarding to reduced bank lending and profitability.

Policymakers have been particularly wary of potential financial stability risks that might attend the use of NIRP. The accommodative monetary policy reaction to the low equilibrium real rates experienced across many advanced economies may have contributed to a rise in risk-taking ('search for yield') among investors and weaker bank profitability, trends that negative rates could intensify. But these potential costs of NIRP must be set against the benefits it brings by helping central banks to achieve their macroeconomic objectives of

[1] The interest rate on the central bank's deposit facility is a 'floor' below which other equivalent nominal rates of return cannot fall. A negative deposit facility rate is a necessary but not sufficient condition for central bank lending facilities to carry a negative nominal interest rate.

supporting growth and inflation. The merits or otherwise of NIRP must also be considered relative to the available alternatives, such as quantitative easing.

This paper assesses the merits of NIRP by surveying the growing body of research that has grown out of the experience with the policy to date. Although several existing surveys also cover NIRP as part of broader assessments, these either discuss the effects of other unconventional monetary policies, including quantitative easing and forward guidance (Bhattarai and Neely, 2016; Dell'Ariccia, Rabanal, and Sandri, 2018; Kuttner, 2018; Lombardi, Siklos, and St. Amand, 2018; and CGFS, 2019), cover low interest rates more broadly (CGFS, 2018), or consider just one aspect of NIRP (e.g., Brown, 2020, on NIRP and bank lending). However, the specific aspects of negative rates deserve a deeper discussion, and so in contrast to other surveys, this paper focuses on NIRP, and covers a broad range of its effects.[2]

Our survey starts in Section 2 by discussing in some depth the context in which central banks have adopted NIRP. Following sections present and discuss the impact of NIRP on different classes of financial assets, different types of agents, and overall macroeconomic conditions. When assessing the impact of NIRP, it is important to consider that the estimation of such effects is particularly difficult for many reasons. First, it is challenging to isolate the effect of NIRP, since almost all NIRP announcements have been accompanied by other unconventional monetary policy measures. Second, there are not many instances of policy rate changes in or into negative territory. Third, identification of causal effects is difficult. Studies that allow for clean identification (e.g., by examining the high-frequency response of asset prices or using micro data) only provide indirect evidence on the macroeconomic impact of NIRP. By contrast, studies that try to measure aggregate effects directly face important identification challenges. Fourth, the analysis of NIRP suffers from a selection problem: if countries that expect high costs from NIRP do not implement it, and only economies that expect low costs do, empirical studies may underestimate potential side effects. Finally, NIRP has only been adopted in advanced economies, which limits the scope for exploiting cross-country heterogeneity to identify the role of structural factors in shaping the transmission of NIRP. Despite these challenges, many studies provide evidence on the effects of NIRP on macro-financial variables.

The review of the existing evidence begins by examining the pass-through of monetary policy to market rates and asset prices when NIRP is deployed. As discussed in Section 3, we find no evidence that the use of a negative policy rate has led to weaker effects on money market rates than interest rates changes in positive territory. Negative rates also transmit along the term structure. There is evidence that in most jurisdictions, both short- and long-term yields dropped significantly after policy announcements, with the maximum effects occurring on 2-year yields. The effects appear to be more pronounced for the first cut into

[2] Swoboda (forthcoming) offers a shorter discussion of various aspects of negative interest rates.

positive territory, suggesting that the introduction of NIRP was associated with a significant revision in financial market expectations.

The impact of NIRP on financial intermediaries is central to most policy assessments. Section 4 considers the evidence along a number of dimensions, starting with the pass-through of policy to bank deposit and lending rates. Findings are a little more mixed than those for market rates. For bank deposit rates, some evidence points to deposit rates for households being less responsive than those for firms. Other evidence points to successive rounds of cuts resulting in slower or lower rates of pass-through. Formal statistical tests have generally not found significant changes, however. The effect of NIRP on bank lending rates is expected to depend on the structure of bank balance sheets, because the structure of a bank's assets and liabilities affects how its profitability changes when rates go below zero. There is a lot of heterogeneity among banks in terms of their presumed exposure to the effects of negative rates, some of which has been used to help identify the effects of the policy. Where banks rely more heavily on deposits with rates that are sticky around zero, some studies have found an adverse impact on pass-through. Interestingly though, banks seem not to have substituted away from deposit funding as a result of NIRP. Other research has found that banks with an initially larger share of liquid assets do pass rate cuts in negative territory onto lower lending rates.

Overall, most of the papers we survey conclude that negative rates are passed through to borrowers, albeit with some attenuation for banks whose profits are initially most pressured by the policy. This implies less stimulus to investment, consumption, and economic activity in general than would be expected from rate cuts in positive territory, albeit not dramatically so.

The adverse effects of NIRP appear to come about mostly from a compression of banks' interest margins. Some research has found that cuts into or in negative territory have a larger impact on these margins than cuts in positive territory. The overall effects on bank profitability must factor in offsetting effects from capital gains on the trading book, and smaller loss rates on outstanding loans. Banks have also sought greater fee and commission income to compensate for the relatively greater cost of deposits. Research has identified banks that are small, are not engaged in cross-border lending, face significant competition, are real estate- and mortgage specialists, or operate in countries where floating loan rates predominate, as being most impacted by NIRP. But across the banking sector as a whole, the evidence suggests that profits have not significantly deteriorated.

Banks take on more risk following the adoption of NIRP. The literature uncovers evidence of higher risk-taking both on banking books and trading books. But such findings do not necessarily count against the policy. Some increase in risk-taking is an intended consequence of the policy action, because relaxing the funding constraint on borrowers can help to spur investment and spending, as a vast literature on the financial accelerator has shown

(Brunnermeier et al., 2013). Furthermore, many of the same effects apply to a policy of positive but 'low for long' interest rates. The evidence so far does not indicate that *negative* rates specifically exacerbate *ex post* risks to banks, that is, loans and investments realizing losses.

In the final part of Section 4 we summarize evidence for non-bank financial institutions. Academic papers, and even policy studies, dealing with this type of institutions are relatively scarce. Money market funds, which often offer liquid deposit-like accounts to investors, face particular exposure to negative rates because they hold mostly short-term assets whose returns are closely linked to policy. However, the evidence indicates that the performance of euro area money market funds has held up well. Pension funds and insurers in some areas have sought to hold internationally more diversified portfolios following NIRP.

Central banks turned to NIRP to stimulate economic activity. In Section 5, the final part of our survey, we survey the literature on how real economy actors and macroeconomic aggregates have been affected by NIRP. Unfortunately, we find research on household and firm behavior under negative rates to mostly be either non-existent or inconclusive. Studies of household savings and investor portfolio choices under NIRP are largely absent, although there is some mixed experimental evidence. For firms with higher exposure to negative rates, some studies have found that NIRP led to increases in fixed investment and employment. But others have found firms borrowing from banks that are more impacted by NIRP have lower investment.

The effects that NIRP has had on the macroeconomy also remains sparse. In part, this is because it is challenging to separate the effects of NIRP from those of other concurrent unconventional monetary policy measures as already remarked. Still, a study of the euro area indicates that NIRP seems to have had small but positive effects on inflation and growth, and to have boosted corporate investment. In Japan, NIRP may have supported the economy through the exchange rate channel. Overall, because the available evidence points to negative policy rates having transmitted to asset prices in a similar manner to positive policy rates, it is likely that NIRP has had macroeconomic effects that are comparable to conventional monetary policy. Moreover, there are likely to have been important complementarities between NIRP and other UMPs that have acted to amplify the effects of the individual components of central bank policy packages.

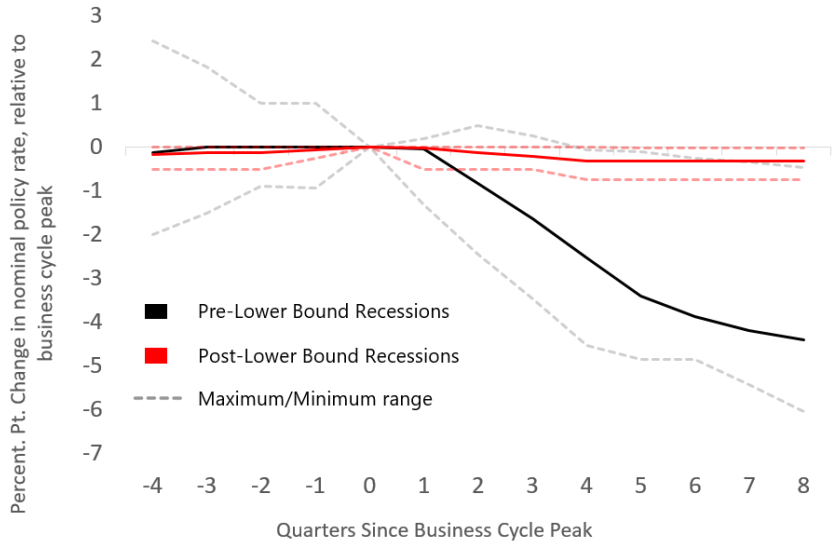
The survey concludes with a summary of the gaps that exist in the literature, and directions for future research.

2. NEGATIVE RATES AS A POLICY OPTION

The global neutral real rate of interest—the level of real rates at which demand equals potential output, and therefore there are no inflationary or deflationary pressures—has been

in decline for decades in response to slow-moving structural forces. In many advanced economies it is estimated to be close to zero (among others, see Del Negro et al., 2019) from a high of close to 3 percent in the early 1980s. With inflation targets of about 2 percent, a low real rate has resulted in very low nominal rates as well. In a recession, and when policy rates are already low, central banks have turned to NIRP as a means to deliver needed monetary stimulus, usually alongside other unconventional policy measures. To illustrate the potential need for NIRP, Figure 1 shows that whereas the median policy easing for advanced economies prior to the substantial decline in neutral rates seen around 2009 (1999 for Japan) was about 5 percentage points, in the following decade central banks could implement only small cuts when recessions struck.

Figure 1. Median Policy Easing During AE Recessions, 1990-2019



Notes: The Chart shows changes (median, min, max) in policy interest rates around business cycle peaks between 1990 and 2019, for the US, Euro Area (Germany until 1999), Japan, Canada, and UK. Business cycle peaks (according to jurisdictional business cycle dating committees): US = 1990Q3, 2001Q1, 2007Q4 | EA = 1992Q1, 2008Q1, 2011Q3 | UK = 1990Q2, 2008Q1 | Japan = 1991Q1, 1997Q2, 2000Q4, 2008Q1, 2012Q1 | Canada = 1990Q1, 2008 Q4. "Pre-lower bound" recessions are taken to be those prior to 2009, aside from Japan for which it references recessions prior to 1999.

A prominent constraint on central banks' ability to set interest rates below zero was long thought to be the existence of physical cash (Hicks, 1937). However, cash is costly to hold in large quantities and impractical for wholesale settlement, and so agents remain willing to hold assets that pay negative nominal returns. So long as cash exists, though, a technical minimum interest rate (the effective lower bound) must exist. The effective lower bound may be well below zero in many economies, and so far no jurisdiction appears to have set a rate low enough to precipitate a material shift into cash (Brandao-Marques et al., 2021). Indeed, estimates of the effective lower bound vary and reflect different assumptions about storage, transportation, and insurance costs associated with holding large amounts of currency. These costs are likely to vary across countries. For instance, storage costs depend on the largest denomination banknote available in each jurisdiction during the implementation of NIRP. Existing estimates suggest effective lower bound is negative in

many countries and below –1 percent in some countries, such as Denmark and Sweden (Rostagno et al., 2016). Estimates for Canada, for example, imply an effective lower bound between –25 and –75 basis points, with a midpoint estimate of –50 basis points (Witmer and Yang, 2015). Similar estimates hold for the Czech Republic (Kolcunová and Havránek, 2018), euro area (Rostagno et al., 2016), and the United States (Burke et al., 2010).

Against this background, many central banks have adopted NIRP in the last decade to achieve their monetary policy objectives. Table 1 provides a timeline of NIRP for economies that have adopted it. In July 2012, the Danish central bank was the first country to cut its main official policy interest rate—the interest rate on bank certificates of deposit—into negative territory, as a means of defending the Danish krone's peg with the euro.[3] To date, the Riksbank is the only central bank to exit from NIRP, when in December 2019 it announced that it would increase the repo rate back to zero citing an inflation rate close to the 2 percent target and an expansion in economic activity.

NIRP has frequently been deployed in concert with other unconventional monetary policies such as forward guidance and quantitative easing. One of the reasons is that these measures may often have mutually reinforcing effects, even if this was not always clear at first. The complementarity in the case of forward guidance is particularly direct, as both policies influence beliefs about the path of interest rates. By influencing beliefs about the lower bound of interest rates, NIRP reinforces the effect of forward guidance announcements that aim to lower long-term yields (Grisse, Krogstrup, and Schumacher, 2017). By reducing the perceived asymmetry in possible future interest rate paths, NIRP can lower long rates.

NIRP can also be seen as a substitute for forward guidance when the credibility of the latter is imperfect. Forward guidance has been deployed when private sector expectations for rate hikes were running ahead of policymakers' own expectations, with announcements inducing a flattening of the yield curve. The efficacy of these forward guidance announcements hinges on their credibility. NIRP, however, is an observable action and can thus be more effective (Sims and Wu, 2020). Furthermore, forward guidance is often viewed as a way to overcome the zero lower bound and NIRP, by allowing the central bank to track more closely the natural rate of interest, in part removes the need for such forward guidance (Rognlie, 2016). The interaction between NIRP and quantitative easing is likely to be more complex. Just like NIRP, quantitative easing also works through a 'signaling channel' (Krishnamurthy and Vissing-Jorgensen, 2011).[4] Therefore, to the extent that the signaling channel of NIRP is

[3] In July 2009, Sweden's Riksbank lowered its deposit rate to –25 basis points. This was to keep the interest rate corridor symmetrical around it main policy rate (repo rate) which was lowered to 25 basis points.

[4] In this view, financial markets may in part interpret asset purchase programs as a commitment by the central bank to keep policy rates low. The signal is credible, so the argument goes, because raising rates while holding a large portfolio of long-duration assets would lead the central bank to take losses, which may lead to political or reputational costs.

material, negative rates may reinforce the effectiveness of quantitative easing in the same manner that they reinforce that of forward guidance. In addition, since quantitative easing flattens the yield curve, NIRP may mitigate negative effect of asset purchase programs on bank profits from maturity transformation by removing the zero lower bound constraint on policy rates, as long as they remain above the reversal rate. However, there are circumstances under which quantitative easing may detract from NIRP. This is because quantitative easing increases the amount of bank reserves and, hence, the burden of NIRP on bank profits. Thus, for a sufficiently large central bank balance sheet, the contractionary bank lending channel may offset the expansionary signaling channel of NIRP (Sims and Wu, 2020).

Table 1. Timeline of NIRP

Country	Instrument	Date	Level
Denmark	Certificates of deposit	6 July 2012	-0.20 percent
		25 January 2013	-0.10 percent
		25 April 2013	0.05 percent
		5 September 2014	-0.05 percent
		20 January 2015	-0.20 percent
		23 January 2015	-0.35 percent
		30 January 2015	-0.50 percent
		6 February 2015	-0.75 percent
		8 January 2016	-0.65 percent
		13 September 2019	-0.75 percent
		20 March 2020	-0.60 percent
Euro Area	Deposit rate	11 June 2014	-0.10 percent
		10 September 2014	-0.20 percent
		9 December 2015	-0.30 percent
		16 March 2016	-0.40 percent
		18 September 2019	-0.50 percent
Japan	Deposit rate	16 February 2016	-0.10 percent
Switzerland	Sight deposits	15 January 2015	-0.75 percent
Sweden	Repo rate	18 February 2015	-0.10 percent
		25 March 2015	-0.25 percent
		8 July 2015	-0.35 percent
		17 February 2016	-0.50 percent
		9 January 2019	-0.25 percent
		8 January 2020	0 percent

3. FINANCIAL MARKETS

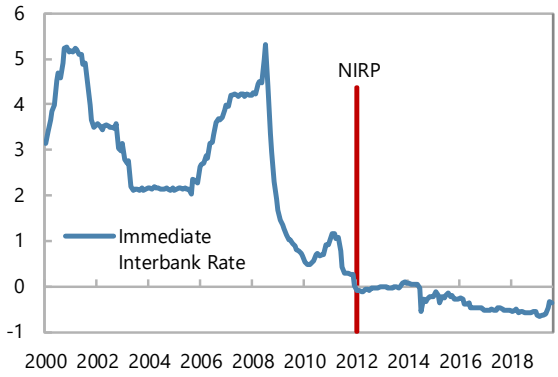
A key question is whether and how the adoption of NIRP affects monetary policy transmission to interest rates and asset prices. In the presence of a properly functioning transmission mechanism, changes in monetary policy rates are reflected in short-term money market rates and passed from there to the entire yield curve of risk-free rates. The term structure, in turn, works as a benchmark to price stocks and other risky assets. NIRP may impair the entire transmission mechanism or hinder the functioning of only specific segments. Therefore, it is crucial to study the impact of NIRP on a broad set of rates and asset prices.

3.1.1. Money Market Rates

Given that money market rates represent the first step in the transmission mechanism of monetary policy, particular attention has been devoted to assessing the effects of NIRP on such rates. Overall, the response of short-term money market rates suggests that NIRP did not cause any impairment in the transmission mechanism. Across jurisdictions, short-term money market rates have tracked policy rates closely as the latter moved into negative territory (Figure 2). NIRP has not weakened the pass-through of policy rates to money market rates in Denmark (Jensen and Spange, 2015), the euro area (Eisenschmidt and Smets, 2018), Japan, Sweden (Angrick and Nemoto, 2017), and Switzerland (Grisse and Schumacher, 2018).

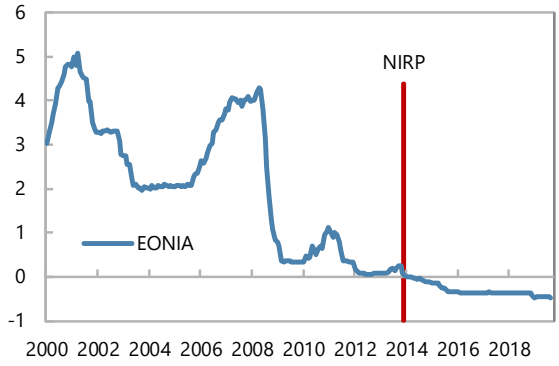
Figure 2. Money Market Rates

Denmark: Money Market Rate



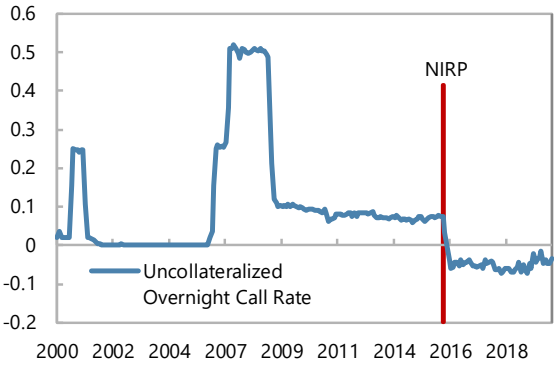
Source: OECD

Euro Area: Money Market Rate



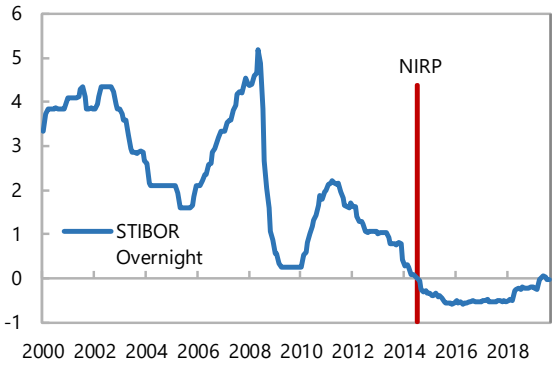
Sources: European Central Bank; Haver

Japan: Money Market rate



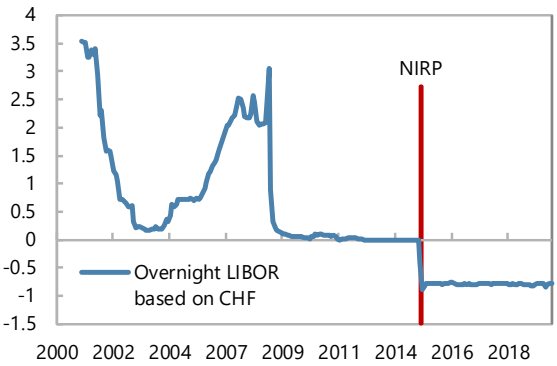
Sources: Bank of Japan; Haver

Sweden: Money Market Rate



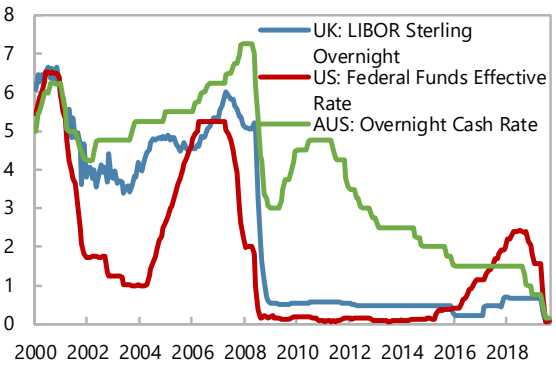
Sources: Sveriges Riksbank; Haver

Switzerland: Money Market Rate



Source: Haver

UK, US, Australia: Money Market Rates



Source: Haver

3.1.2. Yield Curves

In theory, the adoption of NIRP could produce an outsized effect on long-term yields. The reason is that the central bank decision to cut rates into negative territory may lead to a one-time revision in investor beliefs about negative rates. Where the removal (or reduction) of the bound is unexpected, and causes expectations of the path of rates to be materially lower over the medium term, the impact is likely to be stronger and likely be felt further along the term structure (Grisse et al., 2017; and Groot and Haas, 2020).

Looking at the data, yield curves have shifted downwards after NIRP announcements. In particular, government bond yields tend to exhibit an immediate and persistent negative response to the introduction of NIRP (Christensen, 2019). Similarly, Arteta et al. (2016), in a cross-country event study analysis, find that both short- and long-term yields dropped significantly after policy announcements, with the maximum effects of NIRP occurring on 2-year yields. In the euro area, in particular, the cumulative impact of negative interest rates on the yield curve has been almost one to one across the maturity structure (Rostagno et al. 2019). This is substantially more than the estimates of the effect of conventional policy rate cuts (i.e., in positive territory) on long-term yields for the euro area which are from –17 to –45 basis points, according to Brand et al. (2010). The case of Japan, however, seems to have been somewhat different, with NIRP leading to a significant flattening of the yield curve, and explains the subsequent adoption of yield curve control by the Bank of Japan (Westelius, 2020).

Once rates are negative, the impact of interest rate cuts on the yield curve appears to be similar to that of interest rate cuts in positive territory. The response of the yield curve in the euro area to changes in the policy rates before and after NIRP was qualitatively similar (Arteta et al., 2016), especially in the short end of the yield curve (Wu and Xia, 2020). Wu and Xia also suggest that successive cuts of already negative rates affect medium-term yields more strongly, possibly because of the use of forward guidance. Alternatively, the smaller effect of initial policy rate cuts on medium- and long-term yields when compared to later cuts could also reflect changing market expectations about the duration of NIRP.

3.1.3. Exchange Rates

It is conceivable that the sensitivity of the exchange rate to interest rate differentials increases when rates become negative. One reason could be that the adoption of NIRP affects not only the level but also the distribution of the expected policy rates over the medium run (Rostagno et al., 2019). Alternatively, “preferred habitat” effects (Vayanos and Vila, 2021) may cause exchange rates to behave differently once central banks adopt NIRP. For instance, suppose that only cross-border flows by mutual funds and other institutional investors are sensitive to interest rate differentials when rates are positive. However, when central banks adopt NIRP, other capital flows, including bank flows, may also become sensitive to interest rate

differentials. If these assumptions were true, they would imply an increased sensitivity of cross-border flows and exchange rates to interest rate differentials once rates become negative.

Empirical studies examining the effects of NIRP on exchange rates find mixed evidence. Some argue that the impact of NIRP on exchange rates appears to have been short-lived because other domestic and international developments dominated (Arteta et al., 2016; Hameed and Rose 2018; and Viñals et al., 2016). Others conclude that negative interest rates did not have any substantial impact on the behavior of exchange rates (Hameed and Rose, 2018). However, Thornton and Vasilakis (2019) found NIRP to have contributed to weaker currencies and reduced exchange rate volatility.

There is some evidence that NIRP may have increased the sensitivity of exchange rates to interest rate differentials by changing the investor base in currency markets. Lane (2019) shows that the sensitivity of the euro/dollar exchange rate to monetary policy expectations has risen since the introduction of NIRP in the euro area (see also references in Eisenschmidt and Smets, 2019). In Denmark, NIRP may have led to higher banking outflows and depreciation pressures, as banks have switched to holding more foreign assets to offset the costs of their reserves receiving negative interest rates (Khayat, 2018). Moreover, the adoption of NIRP seems to have provided domestic banks in Switzerland with an incentive to raise their foreign currency exposure (Basten and Mariathasan, 2018).

3.1.4. Stock Prices

With respect to asset prices, existing studies focus on the effects of NIRP on equity prices. Although these effects do not seem to be significant in general, bank equities may have suffered. While reporting an overall positive reaction of stock prices to NIRP in Japan, Hong and Kandrac (2018) find the opposite for Japanese banks' stocks. For the euro area, while announcements of unconventional monetary policy (including NIRP) on average benefited banks by increasing their stock prices and reducing their credit default swaps spreads (Altavilla et al., 2018), there is some evidence that the effects of policy rate cuts on bank equity prices have turned negative since official rates went to, or below, zero (Ampudia and Van den Heuvel, 2018; Heider, Saidi and Schepens, 2019; Balloch and Koby, 2020; Bats et al., 2020). Importantly, the more banks rely on deposit funding, the more their stock prices suffer from rate cuts in low- or negative territory. This finding suggests that markets perceive the existence of a zero lower bound on deposits rates as harming bank profitability over the longer term, and so provides indirect support for the mechanism underlying Brunnermeier and Koby's (2016) reversal rate hypothesis, which is discussed below.

4. FINANCIAL INTERMEDIARIES

Among all agents in the economy, the impact of NIRP is likely to be stronger on financial intermediaries, and in particular on banks. The main reason is that the existence of the effective lower bound imposes a lower bound on bank deposit rates, as discussed in Section 2. Importantly, adverse effects on financial intermediaries and credit dynamics are conceivable even above the effective lower bound. The interest rate below which these adverse effects could seriously impair or even reverse the pass-through of policy rates to lending and deposit rates is the 'reversal rate'. The reversal rate may lie above, at, or below the effective lower bound.

Unlike the effective lower bound, the reversal rate depends on the composition of financial intermediaries' balance sheets and income (Darracq Pariès et al., 2020). Consequently, policy measures that affect the structure of intermediaries' balance sheets (e.g., micro- and macroprudential regulations) or the marginal returns to lending, such as TLTRO, as well as implementation details, such as tiering, contribute to determining the location of the reversal rate. For example, in jurisdictions where a material share of credit is provided by banks that rely heavily on retail deposits (which are thought to be sticky at zero), NIRP may have adverse effects on bank profitability, thus increasing the reversal rate.

The terms effective lower bound and reversal rate are often used interchangeably. However, we emphasize that the effective lower bound and the reversal rate represent two different economic concepts. The term effective lower bound is often used to denote a threshold below which the central bank deems it undesirable, rather than infeasible, to cut policy rates beyond, which is instead the reversal rate.

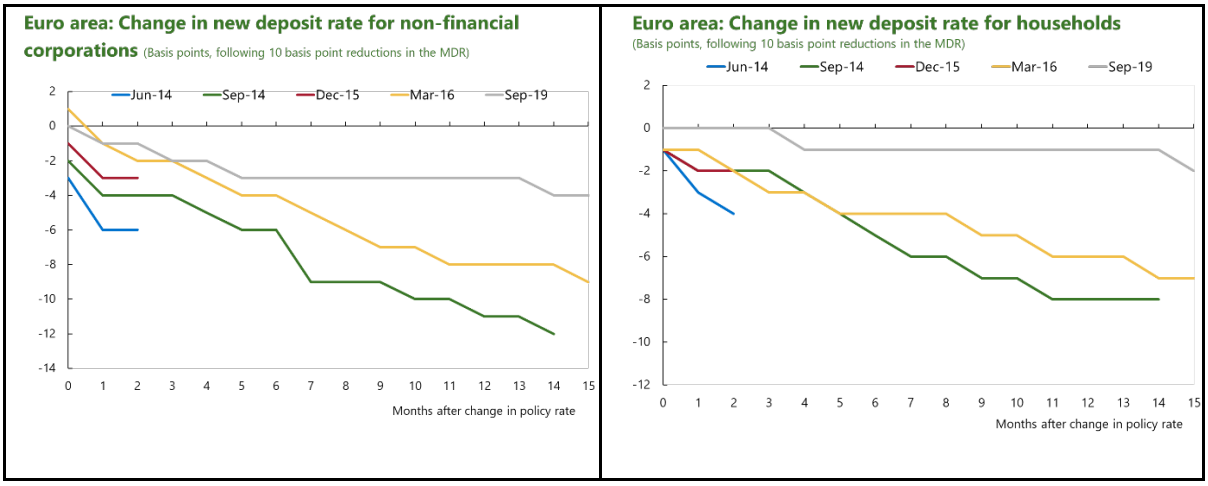
4.1.1. Deposit and Lending Rates

A central question for monetary transmission, especially in economies where banks dominate financial services, is the extent of pass-through from policy interest rates to the interest rates banks offer on their loans and deposits. The observation that pass-through can be less than complete relies in theory on banks possessing some degree of market power in the loan and deposit markets (see Drechsler et al., 2017).

Banks seem to respond to NIRP by increasing fees on retail deposits, while passing on negative rates partly to firms. For retail customers, banks overcome the zero lower bound on deposit rates and reduce their interest expenses by charging higher fees and commissions on retail depositors (Arce et al. 2018, and Bottero et al. 2019 for the euro area; Basten and Mariathasan 2019 for Switzerland). In contrast, for corporate customers, negative rates are transmitted to rates on firm deposits (Altavilla, Burlon, Giannetti, and Holton, 2019; Deutsche Bundesbank, 2020). For European banks, Klein (2020) finds no evidence for a nonlinear relation between policy- and deposit rates at negative policy rates, or for a slower

pass-through, contrary to what is expected in the presence of a zero lower bound for retail deposit rates. By studying Swiss data, Baeriswyl et al. (2021) find that bank deposit rates tend to be sticky at zero.

Figure 3. Bank Deposit Rates



The responsiveness of bank deposit rates to successive policy rate cuts after the introduction of NIRP does not seem to have changed significantly. Deposit rates generally adjust slowly to lower policy rates, meaning that successive rounds of rate cuts have produced smaller and slower reductions in deposit rates. A substantial body of evidence shows that this was the case in the euro area prior to the 2007-09 financial crisis (Andries and Billon, 2016). This may also be true for rate cuts below zero, as Figure 3 suggests, especially for deposits held by nonfinancial corporations. There is little-to-no evidence that the short-term pass-through from policy to deposit rates is statistically different before and after the adoption of NIRP (Madaschi and Pablos-Nuevo, 2017; Brandão-Marques et al., 2021).

NIRP seems to have lowered interest rates on new mortgages and corporate loans. Bank lending rates fell in Denmark after NIRP was introduced, even though the immediate pass-through from policy rates may have declined (see Adolfsen and Spange, 2020). Still, it is not clear whether the lower pass-through to lending rates in Denmark is due to NIRP or to the aftermath of the 2007-09 financial crisis, and Madaschi and Pablos-Nuevo (2017) do not corroborate this for Denmark or Sweden.

There is substantial heterogeneity across banks in the effects of NIRP on lending rates. Bottero et al. (2019) report that NIRP did lower loan rates amongst Italian banks and increased lending—particularly among banks holding larger shares of liquid assets. Similar results have been obtained for Switzerland by Basten and Mariathasan (2018), although they are at odds with Danthine (2018). In Denmark, there is no evidence that banks theoretically more exposed to NIRP (i.e., with a higher reliance on deposit funding) responded differently

than other banks (Adolfsen and Spange, 2020). By contrast, Italian banks with a relatively high reliance on retail deposits tend to increase rates on loans to the nonfinancial private sector (Amzallag et al, 2019), while Japanese banks that are more exposed to NIRP did not lower lending rates as much as other banks (Hong and Kandrac, 2018). According to the findings by Baeriswyl et al. (2021), Swiss banks try to compensate for stickiness of deposit rates by raising lending rates when short-term market rates enter negative territory. Importantly, Ulate (2021b) identifies circumstances related to borrowers' demand for credit under which banks' pricing power is enhanced when rates decline, in a model where deposit rates are assumed to be unresponsive to rate cuts in negative territory (similar to banks with high reliance on deposit funding described above). The model generates realistic pass-through to lending rates in both positive- and negative-rate environments.

4.1.2. Lending Volumes and Asset Quality

When the negative net income effect outweighs the positive net worth effect, cuts in policy rates may hurt lending. Brunnermeier and Koby (2019) develop a simple model in which optimizing banks may respond to rate cuts with higher (rather than lower) loan rates, causing credit volumes to fall rather than to rise. The effect comes about because banks face constraints on their leverage and on their holdings of liquid assets. If negative rates cause bank net worth to decline too much, that leverage constraint becomes binding (Van den Heuvel, 2001 and Disyatat, 2011). To raise profits, banks then optimally choose to charge a higher rate on the marginal loan. At the same time, a binding liquidity constraint leads them to choose a higher deposit rate than otherwise, reflecting the elevated shadow value of liquid assets.

However, other mechanisms may lead banks to lend more or make riskier loans in response to shrinking profitability and low policy rates. On the one hand, when banks have significant market power (the key ingredient for a "deposits channel of monetary policy"), they may respond to lower intermediation margins caused by a policy rate cut by lending more (Drechsler, Savov, and Schnabl, 2017; and 2018). On the other hand, banks may increase risk taking and lend to riskier borrowers if NIRP reduces banks' net worth (see Dell'Ariccia, Laeven, and Marquez, 2014).

According to some studies, banks with more liquid assets and greater access to wholesale funding are able to increase lending more after NIRP. Studies that use different cross-sectional characteristics to measure the exposure to NIRP find a stronger increase in lending by banks with a larger share of liquid assets (Bottero et al., 2019) and more excess reserves with the central bank (Basten and Mariathasan, 2019). Moreover, banks with a lower share of deposit funding increase their supply of credit more (Heider et al., 2019, and Lopez et al.,

2020) or as much as (Bottero et al., 2019) other banks.[5] In addition, Inoue, Nakashima, and Takahashi (2019) and Eggertson et al. (2019) find that in Japan and Sweden, respectively, a larger share of retail deposits is associated with lower lending.[6] The finding that banks that rely more on wholesale funding increase lending more than those that depend more on deposits is in line with the bank lending channel.

Some other studies, however, find that banks that rely more on deposits increase their lending as much, and often more so, than their peers with deposit funding shares. For example, Tan (2019) and Schelling and Towbin (2020) find that banks increase lending, but the effect is stronger for banks with high deposit ratios and which rely more on retail deposits. One explanation for this finding is that banks try to compensate the decline in interest income by increasing lending volumes (Klein, 2020), which would be consistent with Drechsler, Savov, and Schnabl's (2017) deposits channel of monetary policy. The only study that does not find any effect of NIRP on bank lending growth is Michail (2019).

Banks take on more risk following the adoption of NIRP. This result holds in particular for loans (Basten and Mariathasan, 2019; Bottero et al., 2019; and Heider, Saidi, and Schepens, 2019), with some evidence pointing to banks terming out loans (IMF, 2020), but also for securities (Bubeck, Maddaloni, and Peydró, 2020). Furthermore, smaller banks that are more reliant on deposits for funding seem to become riskier (Nucera et al., 2017, Heider, Saidi, and Schepens, 2019, and Schelling and Towbin, 2020), as do those banks with lower capital ratios (Inoue, Nakashima, and Takahashi, 2019) or with stocks that have experienced larger drops in prices following the adoption of NIRP (Hong and Kandrac, 2018). These findings are consistent with Dell'Ariccia, Laeven, and Marquez's (2014) risk-taking channel of monetary policy. By contrast, Arce et al. (2020) find the opposite for euro banks in general and Spanish banks in particular: banks with net interest income more adversely affected by NIRP reduce risk taking in lending to shore up their capital.

However, the overall observed increase in *ex ante* risk-taking does not translate into higher nonperforming loans (*ex post* risk). This is consistent with additional lending to financially constrained firms which lack access to credit but are otherwise profitable (Bottero et al.,

[5] The only study that ranks banks in terms of retail deposits and excess liquidity simultaneously also finds a positive impact of NIRP on lending (Demiralp, Eisenschmidt, and Vlassopoulos, 2019).

[6] Eggertsson et al. (2019) describe a theoretical model of the transmission of monetary policy through the banking system. In their model, banks may respond to negative policy rates by raising the spread between their lending and borrowing rates. The wider spread tends to depress output and inflation, rather than stimulating them as intended. However, this result rests on assumptions that (a) there is one type of liability (deposits) subject to the effective lower bound, (b) the marginal benefit to holding reserves in terms of reduced intermediation costs can be driven to zero, (c) the marginal cost of issuing loans rises as bank profits fall, (d) the central bank attempts to set a policy rate below the effective lower bound. The consequence is that when the central bank sets rates below -0.01 percent (the assumed effective lower bound), it causes bank profits to be lower, and so leads to a contraction in loan supply. See also Ulate (2021a) for a similar exercise that reaches very different conclusions.

2019), but it can also be consistent with NIRP improving the ex-post creditworthiness of borrowers, or simply with nonperforming loans being a lagged indicator of credit quality.

4.1.3. Bank Profits

Potential adverse effects on bank profitability are an important concern for central banks considering NIRP. This is not because the public interest is directly served by banks generating profits for their owners, but because banks that generate healthy returns are able to raise capital at reasonable cost, and because profits can be used to bolster banks' capital resources and so their ability to provide essential intermediation services (e.g., credit) to the wider economy. Finally, banks' ability to provide credit affects the transmission of monetary policy (Kashyap and Stein, 1994).

Banks' net interest margins may suffer because of NIRP. If bank reserves pay a negative nominal interest rate, then bank income will decline if they cannot pass on the cost to their own depositors. Banks typically have some market power because retail customers value the safety and convenience of bank deposits, and because switching accounts to take advantage of better rates is seen as troublesome. But if retail customers are strongly resistant to negative rates, banks that wish to maintain deposit funding must accept lower profits.

On the other hand, negative rates may support banks' net worth by boosting asset values and improving loan quality. The direct impact of NIRP on banks' net interest margins may be offset by positive effects on other sources of income. If NIRP has the intended effect of easing economic conditions, provisioning charges decline along with borrowers' improved ability to repay their loans. For tradeable assets, a similar revaluation may occur, and is reflected in mark-to-market gains. The equity value of the bank is potentially improved through both of these channels. But this benefit is transitory—capital gains are a one-off, and new loans will be priced to reflect better conditions.

Several studies have used bank heterogeneity to identify the effects of NIRP on banks' net interest income and profitability, whose findings are summarized in Table 2. Some have relied on exploiting exogeneity in banks' reliance on retail deposits to make inferences on the importance of the effective lower bound for NIRP. Similarly, many researchers have used the amount of cash-like assets as a proxy for how banks are affected by NIRP. Other approaches classify banks based on their size, business model or responses to dedicated surveys. Finally, some studies simply compare the impact of cuts in official rates to low, but still positive, levels with that of cuts in negative territory.

On average, the evidence suggests that bank profits have not significantly deteriorated, thanks to an increase in lending, the introduction of fees on deposit accounts, and the realization of capital gains. For banks in the European Union, Japan and Switzerland, NIRP only had a small overall effect on profitability because losses in interest income were offset

by gains in non-interest income, such as fees, capital gains, and insurance income (Lopez et al., 2020), or because of lower loan-loss provisions (see Urbschat, 2019 for evidence on German banks). To our knowledge, only Molyneux et al. (2019) find that NIRP adoption significantly squeezed bank profits through a contraction in the net interest margin, which more than offset capital gains on security holdings.

Table 2. Estimated effects of NIRP on bank profitability

Paper	Coverage	Effect on Measures of Bank Profitability
Altavilla, Boucinha, and Peydro (2018)	Euro area	Increase in bank equity prices in response to unexpected cuts in negative territory identified using high-frequency event studies
Ampudia and Van den Heuvel (2019)	Euro area	Decrease in bank equity prices in response to unexpected cuts in negative territory identified using high-frequency event studies
Bats, Giuliodori, and Houben (2020)	Euro area	Decrease in bank equity prices in response to unexpected cuts in negative territory identified using high-frequency event studies
Coleman and Stebunovs (2019)	Europe	Decrease in net interest income when rates are negative (dummy variable)
Hong and Kandrac (2018)	Japan	No change in net interest income, earnings per share, and net total income; decrease in bank equity prices identified using high-frequency event studies
Klein (2020)	Euro area	Decrease in net interest income when rates are negative (dummy variable)
Lopez, Rose, and Spiegel (2019)	European Union, Japan, Switzerland	No change in net income, decrease in net interest income, increase in non-interest income for banks with a higher share of retail deposits when rates are negative
Molyneux, Reghezza, and Xie (2019)	33 OECD countries	Decrease in net interest income and ROA when rates are negative (dummy variable)
Stráský and Hwang (2019)	Euro area	Decrease in net interest income, no change in ROA when rates are negative (dummy variable)
Urbschat (2019)	Germany	Decrease in net interest income, no change in net income from commissions, increase in net income from the valuation of assets and provisions for banks with a higher share of deposits

In relative terms, the income of large banks and those that rely relatively less on deposits performs better under NIRP. Larger banks were also likely to have made use of hedging strategies to protect margins (IMF, 2020). Other studies find that overall bank profitability in the euro area has been largely unaffected by the introduction of NIRP once the total effects of this policy on asset quality are taken into account (Hong and Kandrac, 2018, Altavilla, Andreeva, Boucinha, and Holton, 2019, and Stráský and Hwang, 2019).

Smaller and more specialized banks appear to have been adversely affected. In particular, banks that are small, are not engaged in cross-border lending, face significant competition, are real estate- and mortgage specialists, or operate in countries where floating loan rates predominate, see the biggest declines in profits and net interest margins after the introduction of NIRP (Molyneux et al., 2019). However, Coleman and Stebunovs (2019) find that NIRP adversely affected the profitability of all euro area banks, regardless of their business models, but this policy seems to have accounted for only a small fraction of the difference in profitability between U.S. and European banks.

However, the evidence that the average effect of NIRP on bank profits has been small is not conclusive as it could be capturing only short-term effects, which may be reversed over time. In fact, for positive interest rates, evidence shows that rate cuts initially increase bank net interest margins and profits, but after some time the effect is reversed, consistent with loan pricing frictions (Alessandri and Nelson 2015, and English et al., 2018). When interest rates are negative, a policy rate cut seems to imply a larger drop in net interest margins for European banks than an equivalent cut above zero (Klein, 2020). Finally, the expectation of large adverse medium- to long-run effects on bank profitability, potentially offsetting any temporary increase in profits, could explain the aforementioned evidence on bank stock prices falling after NIRP.

4.1.4. Bank funding structure

There might a two-way relationship between NIRP and the composition of bank liabilities. Negative rates may lead to a fall in the importance of retail deposits as a source of bank funding because households and firms may switch to cash as rates approach the effective lower bound. At the same time, the degree of reliance on retail deposits plays a key role in determining the effects of NIRP, since the cost of other sources of funding, like wholesale funding and bonds, is not constrained by the effective lower bound.

Empirically, NIRP does not seem to have affected banks' reliance on retail deposits. Specifically, the share of household- or nonfinancial corporation deposits over total liabilities has not fallen in any of the relevant economies following the adoption of NIRP. In some cases, for instance the euro area, the reliance on this source of funding has even risen with negative rates (Eisenschmidt and Smets, 2019; Deutsche Bundesbank, 2019). Similar findings are reported by Lopez et al. (2020) for a broader sample of European and Japanese banks.

However, many confounding factors may be at work. For example, the evolution of deposits may reflect the adoption of unconventional monetary policy measures, such as quantitative easing. When the central bank purchases assets directly from households or firms, this mechanically causes an increase in bank deposits held by these sectors. Nevertheless, this

descriptive evidence suggests that neither households nor nonfinancial firms have significantly rebalanced their portfolios away from bank deposits.

4.2. Nonbank Financial Institutions

The adoption of NIRP could potentially induce large outflows from money market funds. Negative nominal interest rates are special for money market funds because, in many jurisdictions, they are in fact a form of narrow banks that issue short-term liquid liabilities and invest in liquid safe assets. Thus, like banks, money market funds face the risk of redemptions when interest rates near the effective cost of holding cash. However, unlike banks, money market funds work with very narrow interest margins because they have a limited ability to tilt the composition of their assets toward riskier, illiquid higher-yield assets. A further complication arises for money market funds that offer constant net asset value (e.g., a constant 1 euro (EUR) per share) with negative rates: such money market fund models are either not sustainable, or forced to recur to share-cancelling mechanisms.[7] Finally, NIRP can encourage money market fund exits because of the effect it may have on fund manager compensation, especially if management fees are a percentage of fund gross yields (Dwyer et al., 2008).

NIRP could exacerbate the search for yield and associated risk taking by other nonbank financial institutions. In particular, life insurance companies and other institutional investors may have an incentive to increase risk taking because of guaranteed positive nominal returns to their policyholders, combined with requirements to hold a certain fraction of their assets as liquid (potentially negative yielding) government securities. It is not clear, however, that this would imply a discontinuity at negative rates in the behavior of these investors. In addition, especially for liability-driven investors such as life insurance companies, low- and negative yields may have the opposite effect and cause them to increase their demand for negative-yielding safe assets (even to the detriment of cash) as they try to hedge duration risk (Domanski et al., 2017; Shin, 2017).

Overall, the evidence suggests that money market funds have weathered NIRP relatively well. Although money market funds saw an increase in redemptions following the introduction of NIRP, at least for the euro area, assets under management by money market funds recovered quickly (ECB, 2015). And, because the assets held by money market funds were generally safe and liquid, redemption-induced liquidations were not disruptive to funding markets. Moreover, the empirical evidence suggests that the level of policy rates is not the key driver of money market fund performance. In fact, the profitability of money market funds mainly depends on the difference between the rate on the central bank deposit

[7] Constant net asset value funds are now banned in many jurisdictions, including in the European Union. In the United States, constant net asset values are not allowed for prime money market funds, but are still allowed for retail and Treasury-only money market funds (McAndrews, 2015).

facility and the yield on short-term debt securities, which typically represent a large share of money market fund holdings (see Bua et al., 2019 for evidence on Irish funds). These results point to the importance of the policy mix, since the gap between the relevant policy rates and short-term government bond yields is influenced by other unconventional monetary policy measures, such as quantitative easing.

Very few studies have examined how life insurance companies and pension funds have fared after the introduction of NIRP. In Denmark, they have seen their profit margins fall since 2012 (Danmarks Nationalbank 2018). This could be because NIRP depresses current interest income, or because legacy policies with significantly positive guaranteed returns have dragged down profitability in a low return environment. NIRP depresses insurers' income for two reasons. First, banks have increasingly passed on negative rates to insurers' and pension funds' deposits, and to a much larger extent than to nonfinancial corporations or households. Second, among domestic investors, Danish life insurers and pension funds are only second to banks as holders of Danish mortgage bonds.

However, in Switzerland, where a majority of pension funds pay negative interest on their bank deposits, the negative effect of NIRP on current interest income has been outweighed by the positive effects on capital gains in fixed income, equity, and real estate (Bauer, Bee, and Weisser, 2019).[8] In Japan, following the introduction of NIRP, insurers' and pension funds' investments in foreign securities increased markedly (Honda and Inoue, 2019).

5. REAL ECONOMY

Most of the existing studies focus on the effects of negative rates on financial variables and bank behavior. As a result, the evidence on the impact of NIRP on other agents in the economy, such as households and firms, is still scant. Interestingly, the evidence on the effects on macroeconomic variables is also quite scarce, even though central banks moved rates into negative territory in order to sustain economy growth and inflation. The next sections provide an overview of the works on these topics.

5.1. Households and Firms

From a theoretical perspective, the introduction of negative nominal rates may induce discontinuities in households' and firms' behavior. NIRP would make cash attractive for some households and firms, especially those with smaller liquid asset balances, and less frequent needs to make larger transactions, deposits may be flightier. Non-linear effects may be conceivable, with massive cash withdrawals occurring if rates become sufficiently negative (IMF, 2017). Moreover, households and firms may suffer from money illusion, or be very uncertain over the rate of inflation, which will make them dislike negative nominal

[8] See also Swoboda (forthcoming) for a discussion on the effect on Swiss pension funds.

rates more than negative real rates.[9] Such attitudes may combine with preferences which are not in line with standard expected utility theory (e.g., Kahneman and Tversky's, 1979, 'prospect theory' or Diecidue and Van de Ven's, 2008, 'loss probability aversion') that could induce a sudden shift in household and firm portfolio choices following the introduction of negative rates (e.g., into more risky assets).

Unfortunately, empirical studies of the response of household savings and portfolio choices to NIRP are largely absent. We are not aware of any empirical study of changes in investor behavior using microdata, although there is some mixed experimental evidence (Baars, Cordes, and Mohrschladt, 2020; Bracha, 2020; Corneille et al., 2020; Efendic et al., 2019). The evidence on how NIRP affects firm behavior is mixed. On the one hand, in the euro area, firms with relationships with banks that pass through negative interest rates to corporate deposits increase their fixed investment (Altavilla, Burlon, Giannetti, and Holton, 2019). This effect comes mostly from firms with high cash holdings. In Denmark, nonfinancial firms more exposed to negative deposit rates increased fixed investment and employment and reduced their leverage and bank deposit holdings (Abildgren and Kuchler, 2020). On the other hand, micro-evidence for Japan suggests that nonfinancial firms curtail investment if they borrow from banks with greater exposure to negative rates (Inoue, Nakashima, and Takahashi, 2019). In addition, a 2017 survey by the ifo Institute found that about 30 percent of firms affected by negative deposit interest rates reallocated their financial portfolios to other investments and repaid loans, but only 11 percent increased their fixed investment (Hainz, Marjenko, and Wildgruber, 2017).

5.2. Macroeconomic Variables

Although direct evidence on the overall effects of NIRP on inflation and output is scarce, overall, it suggests a significant macroeconomic effect. For example, depending on the importance of bank equity for the transmission mechanism of monetary policy, the efficiency of negative nominal rates is between 60 percent and 90 percent of positive rates (Ulate, 2021a). On average, countries that have adopted NIRP have seen higher growth and inflation expectations (e.g., Czudaj 2020). In addition, for the euro area, Rostagno et al. (2019) report that NIRP is responsible for about a fifth of the overall impact of unconventional monetary policies on output and inflation over the period 2015-2018. There is also evidence that, in Japan, post-NIRP monetary policy has had similar macroeconomic effects as pre-NIRP policy (Villanueva, 2021). On the other hand, Michail (2019) uses a counterfactual estimation technique and find that the impact of NIRP did not have a significant effect on inflation in in Denmark, Sweden and Switzerland.

[9] In fact, in surveys of household inflation expectations, sizable proportions of respondents choose "Don't know" as a response to questions about near-term inflation rates (Coibion, Gorodnichenko, and Weber, 2019).

All in all, the available evidence suggests that the estimated effect of interest rate cuts on output under NIRP is comparable to those of conventional policy rate cuts and quantitative easing, but the effects on inflation or inflation expectations may have been modest (e.g., Rostagno et al., 2019). Moreover, the results suggest that all countries that have implemented NIRP have yet to reach the reversal rate, which may be at or below -1 percent (Darracq Pariès et al., 2020).

6. CONCLUSIONS

Many observers remain distrustful of negative nominal interest rate policies. But nearly a decade after their appearance, most concerns have failed to materialize or have turned out to be less relevant than expected. Economists and policymakers have identified a number of potential drawbacks of NIRP, but none of them have emerged with such an intensity to tilt the cost-benefit analysis in favor of removing this instrument from the central bank toolbox. The research surveyed in this paper indicates that the transmission mechanism of monetary policy does not appear to change significantly when official rates become negative. And overall, bank profitability has not significantly suffered so far. The reversal rate remains a theoretical concept which has not been empirically validated and, most likely, not yet breached (Arce et al., 2020), and banks appear to have not engaged in excessive risk-taking. Of course, these side effects may still arise if NIRP remains in place for a long time or policy rates go even more negative, approaching the reversal rate.

The literature so far has largely overlooked the impact of negative interest rates on financial intermediaries other than banks. Although pension funds and insurance companies do not typically offer overnight deposits, so that the constraint on lowering the corresponding rates below zero is not relevant, other non-linearities may arise when market rates become negative, possibly due to legal or behavioral constraints. Given the importance of these institutions, the absence of empirical evidence on NIRP on their behavior is surprising. The role of bank competition in shaping outcomes is not yet well understood. As highlighted in IMF (2017), absent competition from other intermediaries or capital markets, the transmission of negative policy rates to bank lending rates will be weaker, as banks would try and preserve their intermediation margin. To the best of our knowledge, no study has tested this hypothesis, despite the availability of relevant data.

Another interesting direction for future research is to further study the determinants of the corporate channel identified by Altavilla, Burlon, Giannetti, and Holton (2019). According to this channel, cash-rich firms with relationships with banks that charge negative rates on deposits are more likely to use their liquidity to increase investment. However, the specific mechanisms at work remain to be investigated.

Finally, few studies have examined cross-border spillovers of NIRP (Arteta et al., 2016, Fukuda, 2018, Varghese and Zhang, 2018, and Feldkircher et al., 2020 being the exceptions) and no comprehensive, systematic assessment exists.

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