Expanding the Unconventional Monetary Policy Toolbox: Central Bank Lending Programmes*

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Abstract

Using a DSGE model, this paper studies the interactions between Central Bank lending programmes and three other unconventional monetary policy (UMP) instruments: Quantitative Easing, Forward Guidance and Negative Interest Rate Policy. The lending programmes feature a collateral policy and a "dual rate system", in the spirit of the ECB strategy during the Covid-19 crisis. We find that the synergies between the lending programmes and the other UMP instruments make three cases for their simultaneous deployment. First, when the lending programmes are deployed *simultaneously with QE*, synergies — working through the collateral value — and trade-offs — generated by the scarcity of available assets — arise. By setting its collateral policy while engaging in QE, the Central Bank can strengthen the synergies and overcome the trade-offs, improving monetary policy effectiveness. Second, when the lending programmes are deployed *simultaneously with NIRP*, the dual rate system supports financial intermediaries' net worth. This synergy prevents the economy from hitting the reversal interest rate, again increasing monetary policy effectiveness. Finally, once the economy is in recovery, the smooth, complete, *simultaneous unwinding* of both QE and the lending programme ensures the most effective normalisation policy.

"The anatomy of our response [to the Covid-19 crisis] consists of a carefully calibrated set of three mutually reinforcing and complementary components. The first component relates to broad-based asset purchases [...]. The second component consists of [...] targeted longer-term refinancing operations (TLTROs), as well as a comprehensive set of collateral easing measures. And the third component relates to our traditional role as a lender of last resort."

Isabel Schnabel, ECB Executive Board Member, April 2020

*Preliminary and incomplete.

†Any views expressed are solely those of the author and so cannot be taken to represent those of the Bank of England or to state Bank of England policy. This paper should therefore not be reported as representing the views of the Bank of England or members of the Monetary Policy Committee, Financial Policy Committee or Prudential Regulation Committee.

1 Introduction

1.1 Introduction

The Funding-for-Lending Programmes are long-term, collateralised loans that central banks provide to banks at favourable costs in order to enhance the transmission of the policy stance. Since 2011 the European Central Bank (ECB) and Bank of England (BoE) have used this non-standard tool extensively in response to the severe malfunctioning (in same cases dry-up) of the interbank market.[1] The lending programmes lowered banks' funding costs, spurred lending to the real economy, supported output and helped control inflation.[2] More recently, central banks resorted to lending programmes in response to money market malfunctioning induced by the Covid-19 crisis [Cavallino and Fiore, 2020]. Relative to previous liquidity provisions, these programmes featured a *more sophisticated* framework — providing additional degrees of policy freedom[3] — and, critically, they were deployed *simultaneously* with the other unconventional monetary policy (UMP) instruments — generating powerful interactions [Schnabel, 2020a].[4] These new, defining characteristics made the lending programmes "a central bulwark against the impairment of the bank-based transmission mechanism of monetary policy" during the Covid-19 pandemic [Barbiero et al., 2021]. Nonetheless, little is known by the literature on how to design these types of liquidity provisions [Carpinelli and Crosignani, 2021].

The aim of this paper is to explore theoretically and to quantify the synergies and trade-offs between the lending programmes and three UMP instruments: quantitative easing (QE), negative interest rate policy (NIRP) and forward guidance (FG). The motivation is threefold. First, the main transmission channel of the lending programmes — to lower banks' funding costs[5] – is different from the transmission mechanism of other UMP tools. Hence, assessing the effectiveness of the current monetary toolkit requires the lending facility to be fully modelled: QE, despite its liquidity channel [Busetto et al., 2022], cannot be taken as proxy for the lending programmes.

Second, while the literature has explored the link between credit supply and central bank's liquidity injections, it has not yet accurately micro-founded the lending programmes to reflect policymakers' choices. In particular, previous theoretical studies do not include the three main features of the framework

[1] Following the Global Financial Crisis, the ECB in 2011 launched two 3-year Longer-Term Refinancing Operations (LTROs), followed in 2014 by three rounds of Targeted LTROs (TLTROs); the BoE introduced in 2012 the Funding for Lending Scheme (FLS) and in 2016 the Term Funding Scheme (TFS). Critically, the amount that banks could borrow under the TLTROs, FLS and TFS was conditional on their loans to firms and households.

[2] For more details, see [Rostagno et al., 2019a] on the ECB's lending programmes and [Eberly et al., 2020] on BoE's TFS, amongst the others.

[3] For instance, in regard to the ECB lending programme: "The conditional pricing of TLTROs below the deposit facility rate has created additional room for easing funding conditions for banks in a negative interest rate environment and offers an effective backstop against strains in banks' access to market-based funding." [Barbiero et al., 2021]

[4] See [Churm et al., 2021] for the BoE and [Lane, 2019] for the ECB.

[5] See [Churm et al., 2021] for BoE and [Lane, 2020b] for ECB.

implemented during the Covid-19 pandemic: i) the collateral policy, defined as changes in collateral needed to access the lending facility,[6] ii) the "dual rate system", that sets the interest rate on the lending facility separately from the policy rate, and iii) the borrowers' duality, allowing not only financial firms but also corporates to borrow from the central bank (e.g. Wall Street vs Main Street Lending Programs). Missing these specific design features, the literature does not capture several channels of monetary policy transmission, hamstringing the validity of the model for policy's purposes.

Finally, so far the literature has analysed the lending programmes, QE, NIRP and FG in a piecemeal fashion. These *ad hoc* frameworks overlook the interactions amongst the instruments [7] providing an incomplete transmission mechanism of monetary policy, again weakening the usefulness for policy analysis.

In short, as the financial system and the central bank's toolkit evolved, so did the lending programmes: In the words of BoE [Hauser, 2021b], there is "a new generation of central bank tools aimed at market dysfunction". These modern liquidity provisions are more sophisticated than those following the canonical Bagehot principle,[8] as such they call for a new framework of analysis, necessary to capture the novel channels of transmission. The introduction of a unified framework is one of the main aims of this paper.

This paper micro-founds the liquidity injections following the ECB TLTRO and it sets them within the model developed by [Sims and Wu, 2020] featuring multiple UMP tools: QE, NIRP and FG. *This unified framework allows us to explore and assess the strength of the different transmission mechanisms and interactions.* The modelling contributions are the following: on the financial intermediary's side, we include the possibility to access the central bank lending programme as in [Quint and Tristani, 2018], subject to a collateral constraint à la [Kiyotaki and Moore, 1997]; on the central bank side, we add the possibility to lend to intermediaries — while deploying QE, NIRP and FG. Mirroring the most recent ECB TLTRO, the central bank toolkit is expanded with three instruments: i) the collateral's haircut, ii) the choice on the assets eligible for collaterals, and iii) the rate applied to the liquidity provisions.

We make five main contributions. First, when deployed in isolation, liquidity injections are as effective as central bank corporate bond purchases and more effective than sovereign bonds purchases in supporting aggregate demand. Given

[6] "Collateral and haircut policies have gone under the radar for a long time, and in any case have been less popular measures of the monetary policy stance than interest rates or quantitative policies. Yet they are not only essential for the correct functioning of the monetary and financial systems [Bindseil et al., 2017], but are also a key instrument to tighten, or loosen, liquidity in the banking system"[Legroux et al., 2018].

[7] The ECB estimates that its QE — the Pandemic Emergency Purchase Programme (PEPP) decisions in March and June 2020 and the scaling-up of the Asset Purchase Programme (APP) decided in March 2020 — and long term lending programmes lunched in response to the Covid-19 pandemic added 1.3 percentage points to real GDP growth up to 2022 [Hutchinson and Mee, 2020].

[8] Lending freely, to sound institutions, against good collateral, and at rates higher than those prevailing in normal conditions [Bagehot, 1873].

the political economy challenges posed by large QE programmes of corporate bonds,[9] the lending programmes offer an equally effective alternative when the economy hits the ZLB.

Second, when deployed simultaneously, QE and the lending programmes give rise to both synergies that amplify UMP effectiveness and trade-offs that weaken it. The synergies are fuelled by the portfolio rebalancing channel of QE that increases the collateral value, allowing more liquidity injections without using additional monetary policy space (no haircut, nor dual rate easing). In other words, when QE and the liquidity provisions work in unison, UMP effectiveness increases. The trade-off surfaces when the central bank, through its asset purchases and (unchanged) collateral requirements, generates a scarcity of available assets (the contractionary scarcity channel). In this case, QE and the liquidity provisions work in opposite directions, weakening UMP effectiveness. BoE [Hauser, 2021b] stated that "we cannot rely on central bank medicine of the scale and duration seen in 2020 every time we see an inflammation [of market dysfunction]": these results are important to design policy interventions carrying fewer costs in terms of central bank balance sheets and mispriced private sector risks.

Third, easing the lending programme's collateral policy while engaging in QE enhances UMP effectiveness, overcoming the scarcity channel. Compared to relying on QE alone, the concerted strategy allows the economy to achieve a higher degree of output stabilisation with a smaller balance sheet intervention. From a policy perspective, this strategy confirms the ECB response during Covid, characterised by "three mutually reinforcing and complementary components": QE, TLTRO with collateral policy and liquidity injections as lender of last resort.

Fourth, deploying simultaneously NIRP and the lending programme with the dual rate strategy enhances NIRP effectiveness. This synergy arises because the dual rate policy mitigates the contraction in banks' net worth induced by NIRP. From a policy perspective, this concerted strategy makes monetary policy more effective: compared to relying solely on NIRP, the dual delivery achieves a higher degree of output stabilisation with a less aggressive implementation of NIRP. This translates into a smaller probability of hitting the reversal interest rate ([Lagarde, 2020]), the tipping point at which expansionary monetary policy turns contractionary.

Finally, turning towards the normalisation of UMP, we find that the pace of unwinding and the combination of tools that are unwound have significant effects on the performance of the economy during the recession, the recovery and future crises. The most effective strategy is a smooth and complete unwinding of both QE and the lending programme. If this was not possible, QE should be exited quickly and the lending programme carried forward. Compared to never fully unwinding the unconventional stimulus, this strategy leaves the economy less dependent on central bank's interventions and, going forward, more reactive

[9] See the experience of the Bank of England Asset Purchase Facility Schemes: at the end of December 2021 it held GBP875 billion in Gilts and only GBP20 billion in corporate bonds

to them, ensuring the effectiveness of future monetary policy decisions. To conclude, the knowledge on the exit from UMP is limited, leaving "policymakers uncertain about the effects of their policy on the economy"[Panetta, 2022b] — My findings offer the first policy recommendations.

The remainder of the paper is organised as follows. Subsection 1.2 and 1.3 describe, respectively, the distinctive features and channels of transmission of the ECB TLTRO, deployed in response to the Covid-19 crisis, informing the modelling. Section 2 presents a short review of the relevant literature. Section 3 explains the main features of the model, focusing on the financial intermediaries and the central bank. Section 4 shows the calibration of the model. Section 5 presents the simulations above the ZLB, useful to understand the mechanics of the model and to explore the transmission channels of the liquidity provisions. Section 6 presents five policy experiments: first, we simulate exogenous UMP shocks, to compare the effectiveness of the different UMP instruments. Second, we simulate exogenous QE shocks to explore synergies and trade-off between QE and the lending programme. Third, we endogenise both QE and the lending programme, allowing the central bank to deploy these instruments simultaneously in response to a credit shock: this experiment replicates the ECB strategy during the Covid-19 crisis. Fourth we study the synergies between NIRP and the dual rate policy of the lending programme, letting the central bank engage with these tools in response to a credit shock. Fifth, we focus on the policy normalisation, studying the effects on output and central bank balance sheet of different tightening paces and combinations of QE/lending programme. Finally, section 7 concludes.

1.2 The ECB Lending Programmes: novel, distinctive features

This paper micro-founds the lending programmes following the choices of the ECB, a central bank that in response to the Covid-19 pandemic has relied extensively on liquidity injections and developed a highly sophisticated framework. This section presents the characteristics of the ECB Funding-for-Lending Programmes, informing my modelling choices. It is important to fully understand the main features of these programmes because they inform many of the modelling choices made in this paper.

The ECB in 2019 launched the third round of the Targeted Longer-Term Refinancing Operations (TLTRO III). This decision was taken to avoid "congestion effects" in bank funding markets that would have otherwise materialised because of the need to replace expiring TLTRO II funds[Barbiero et al., 2021]. As of June 2021, the TLTRO III became the largest liquidity injection in the history of the ECB: EUR2.2 trillion were provided to fill the liquidity needs of households and corporates triggered by the Covid-19 pandemic (see Figure 1 below). The characteristics of the TLTROs — critical for our modelling — are:

- **Interactions with other unconventional monetary policy tools.**

TLTROs are part of a set of *complementary* monetary tools, including QE, NIRP and forward guidance.[10] The ECB found that the TLTROs worked in unison with the broader policy package, generating interactions that enhanced the lending programme's effectiveness [Barbiero et al., 2021].

- In March 2020 the ECB recalibrated the pre-existing TLTRO III as follows:
  - **Collateral policy.** A core element of the ECB's monetary policy response to the coronavirus pandemic has been the easing of the collateral criteria governing the access to the TLTRO. The Governing Council: i) expanded the banks' borrowing allowance under TLTRO III from 30% to 55% of the eligible loan book, thanks to a 20% reduction of collateral haircuts, amongst other measures; ii) enlarged the set of assets eligible for collateral, including: government guaranteed loans[11] as well as assets (and their issuers) that met the collateral eligibility criteria at the beginning of April 2020, regardless of future downgrades. With this decision, the ECB protected credit from any potential vicious cycles. For more detail on the ECB collateral policies during the Covid-19 crisis, please see [ECB, 2020a] and [ECB, 2020b].
  - **The "Dual Rate System".** The ECB Governing Council reduced the interest rate applied on TLTROs to a rate as low as -1% until June 2022 for banks fulfilling the lending requirements [ECB, b]. This gave rise to the "dual rate system", namely setting the TLTRO interest rate lower than the interest rate on reserves (already negative).[12]

Overall, the TLTROs were "enhanced" along three dimensions: i) the delivery, that became simultaneous with the other UMP tools; ii) the recalibration, that ensured collateral availability; and iii) the pricing, that secured central bank funding at advantageous terms. These three features of the TLTROs played a "key role in preserving favourable bank financing conditions" during the Covid-19 pandemic [Barbiero et al., 2021] and they are fully fledged modelled in our framework.

[10] See [Rostagno et al., 2019b] and [ECB, a]

[11] Allowing banks to receive liquidity against loans covered by the new Euro Area guarantee schemes implemented in response to the Covid-19 pandemic.

[12] In the words of ECB chief economist [Lane, 2020a]: "An important innovation is that, by setting the minimum borrowing rate at 25 basis points below the average interest rate on the deposit facility, we are effectively lowering the funding costs in the economy without a generalised reduction in the main traditional policy rates".

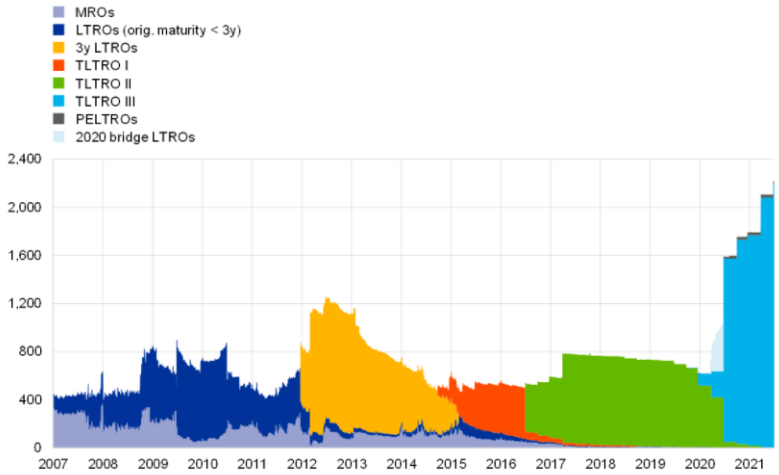


Figure 1: Borrowing from the Eurosystem (EUR billion)

1.3 The Lending Programmes' transmission mechanisms

The transmission of the "enhanced" liquidity provisions to bank lending works through several channels of transmission, beyond the canonical liquidity channel at work in the Bagehot principle [Bagehot, 1873]. Given the key role played by these new transmission mechanisms in supporting credit flow [Barbiero et al., 2021], our model needs to capture them if we want to deliver policy analysis and offer policy prescriptions. Before going into the specific features of the model, it is important to understand how each of these channels work, how they differ and how they may complement or work against each other as a result of different monetary policies.

This section explains four transmission mechanisms of the Lending Programmes that arose during the Covid-19 pandemic and that are at work in our model: i) liquidity channel, ii) collateral channel, iii) "dual rate channel"and iv) scarcity channel.[13]

1. **Liquidity channel**. One of the main functions of banks is to engage in liquidity transformation, as they hold illiquid assets but fund themselves through liquid liabilities [Diamond and Dybvig, 1983]. This process is critical to support the flow of credit in the economy. However, it also makes

[13]For completeness, we highlight two additional transmission mechanisms that have been documented by the literature but that are not present in the model: the maturity extension channel [Carpinelli and Crosignani, 2021] and the Liquidity Coverage Ratio channel [Gocheva et al., 2022]. The maturity extension channel arises because the central bank lending provisions are longer dated that standard refinancing operations, reducing banks' rollover risk [Carpinelli and Crosignani, 2021]. The Liquidity Coverage Ratio (LCR) channel, instead, is triggered when, following central bank liquidity injections, the LCR increases and the financial intermediaries takes actions to reduce it, typically by providing more credit. See [Gocheva et al., 2022] and [Barbiero et al., 2021].

the financial system inherently fragile [Chen et al., 2020]: since banks do not hold enough liquid assets to satisfy the immediate withdrawals of all depositors, if funding dries up, financial intermediaries are forced to liquidate their assets through fire sales. As asset prices drop, intermediation breaks down and credit growth stalls. By providing banks funding in periods of market distress — the direct liquidity channel of the lending programmes — central banks prevent market dysfunction, supporting access to credit [Carpinelli and Crosignani, 2021]. The ECB distinguishes also an indirect liquidity channel: as banks access the TLTRO, they reduce bond issuances, leading to a decline in bond supply and, consequently, lowering funding costs also for those intermediaries not taking part in the central bank's programme [Barbiero et al., 2021].

2. **Collateral channel.** The provision of central bank's liquidity is granted upon eligible collateral. While this notion is rooted in the canonical Bagehot principle [Bagehot, 1873], the ECB used it to gain three additional degrees of policy freedom. In other words, by changing the eligibility of collateral through three different mechanisms, the ECB increased TLTRO take-up, enhancing the transmission of policy stance. The three novel collateral-based mechanisms are the following, and they are all present in our framework:

    - The *quantity* of the collateral: the haircut. The haircut is a reduction in the value of an asset. In the context of the lending programmes, the haircut — set by the central bank — defines the amount of central bank liquidity the intermediary can borrow by pledging its assets as collateral. A lower haircut translates into more central bank liquidity. [Carpinelli and Crosignani, 2021] defined this mechanism as the "collateral relaxation channel".
    - The *quality* of the collateral. The central bank can tighten or ease the access to its lending provisions also by changing the set of assets eligible for collaterals. By lowering the collateral's credit quality requirement — in other words, by accepting securities that do not qualify as high-quality liquid assets — the central bank enlarges the pool of assets that can be pledged, fuelling participation in its lending programme. This transmission channel provides leeway to policymakers when credit rating downgrades shrink the pool of eligible assets and their scarcity can impair the effectiveness of the lending programme [ECB, 2020b].
    - The *value* of the collateral. In the same way as higher net worth in housing makes it easier for households to borrow,[14] higher value of assets eligible for collateral increases banks' borrowing from the central bank. This is the financial friction of [Kiyotaki and Moore, 1997] and [Iacoviello, 2005]: credit limits are affected by the price of

[14] Because houses are used as collaterals for loans.

the collateralizable assets. Policymakers can trigger this collateral-based transmission mechanism by deploying monetary policy tools in unison: for instance, asset purchases increase asset prices, indirectly supporting the value of collaterals, and the lending programme's participation.

3. **The "dual rate channel"**. NIRP is deployed by setting negative interest rate on reserves. However, the inability to pass on negative rates to depositors results in the deposit rate remaining non-negative [Schnabel, 2020b]. Critically, this rate dichotomy shrinks Net Interest Margins (NIM), reducing net worth. As banks' capital falls, intermediation slows down: with banks unable to purchase as much debt, bond yields increase, slowing investment and aggregate demand. This is the contractionary channel of NIRP [Sims and Wu, 2020] that, if strong enough, can bring the economy to hit the reversal rate: the turning point when accommodative monetary policy turns contractionary [Brunnermeier and Koby, 2018]. In order to alleviate this tightening effect, the central bank can set the interest rate on its lending facility — representing a funding cost for the bank — lower than the interest rate on reserves, alleviating the capital loss resulting from NIRP. As a result, intermediation does not break down, sustaining asset prices and output growth [Lagarde, 2020]. This expansionary transmission mechanism is the "dual rate channel", observed with interest also by BoE External MPC Member [Saunders, 2020].

4. **Scarcity channel**. The introduction of the lending programme generates a pent-up demand for assets, especially high quality liquid assets, since they are used as collateral to access the central bank's facility. The pent-up demand for assets affects the availability of collateral, with effects on "prices, rates, and price volatility of assets": this is the scarcity channel first analysed by [BIS, 2015]. This transmission mechanism is at work in the Euro Area where it is strengthened by the ECB asset purchases, as they further fuel asset demand [Corradin et al., 2017].[15] There is increasing evidence from the literature that this excess demand (not matched by a higher supply of assets) compresses spreads, hurting banks' net worth and monetary policy effectiveness.[16]

To conclude, this section has shown that the "enhanced" lending programmes are transmitted in a more complex, multifaceted way than originally described by the Bagehot principle. In the words of the ECB "The stimulus coming from

[15] See [Grandia et al., 2019], [Schnabel, 2022], [Bailey et al., 2020a]and [BIS, 2019].

[16] [Bailey et al., 2020a]: "market functioning may deteriorate if a central bank's holdings of securities are particularly large compared to outstanding amounts. [...] beyond a given point, central bank purchases of safe assets may reduce the liquidity resilience of the financial system as these assets are no longer available for non-banks to hold". The same message is delivered by [Schnabel, 2022], Member of the Executive Board of the ECB "[...] years of balance sheet expansion have caused the bond free float in some economies to decline to very low levels. As such, an end to net asset purchases enhances the availability of safe assets that the market requires to function well."

the enhanced operations was transmitted *above and beyond* the explicit lending criteria ingrained in the programme". Our model of UMP capture all these various transmission channels.

2 Literature

This paper relates to three streams of literature applying DSGE models: the studies on UMP and more specifically on the lending programmes; the recent research on the unwinding of UMP; and finally the studies on NIRP and the reversal interest rate.

The papers that study UMP with DSGE models typically introduce the non-standard tools in a piecemeal fashion.[17] This modelling choice does not reflect policy experience nor policymakers' preferences.[18] Therefore, we contribute to the theoretical literature on UMP by analysing QE, NIRP, FG and the lending programmes *in a single framework*, extending [Sims and Wu, 2020]. Focusing on the lending programmes, there is a burgeoning empirical literature on the effects of the liquidity injections[19] while the theoretical papers have not yet accurately micro-founded the lending programmes to reflect policymakers' choices. Attempts by [Quint and Tristani, 2018] and [Cahn et al., 2017] include only one channel of transmission — the liquidity channel — while [Furkan Abbasglu et al., 2019] and [Schabert, 2015] take a step further including the collateral channel. Building on these papers, we contribute to the lending programmes' literature by adding a channel of transmission that defined the ECB TLTRO during the Covid-19 pandemic — the dual rate channel — and another transmission mechanism at work in the Euro Area, the scarcity channel [Schnabel, 2022]. The rich micro-foundations increase the validity of the model for policy purposes.

We contribute also to the recent literature on UMP normalisation. Papers investigating UMP have typically studied the delivery of UMP tools during the easing cycle of monetary policy, avoiding exploring their unwinding during the tightening cycle. The lack of empirical literature on UMP unwinding is due to the scarce engagement of central banks with UMP normalisation: before the current tightening phase, Quantitative Tightening has been attempted only by BoJ in 2006 and the Fed in 2017 [BIS, 2019]. Equally thin is the theoretical literature, with two notable exceptions: [Karadi and Nakov, 2021] and [Sims and Wu, 2020]. These authors provide policy recommendations on the *pace* of UMP normalisation, but they do not give insights on the *combination* of instruments that are unwound. We show that both the pace of the unwinding

[17] For instance [Gertler and Karadi, 2013] for QE and [Wu and Xia, 2018] for NIRP. See [Kuttner, 2018] for a review of the research on UMP that has been carried out since the Global Financial Crisis.

[18] UMP tools have been deployed simultaneously both during the Global Financial Crisis and the Covid-19 pandemic. In addition, the ECB in its strategy review found that "a combination of instruments is generally more efficient than relying on a single tool" [Altavilla et al., 2021].

[19] Amongst the others, see: [Carpinelli and Crosignani, 2021], [Crosignani et al., 2020] and [García-Posada and Marchetti, 2016].

and the combination of tools that are unwound matters for the performance of the economy during the recession, recovery and future crises.

Finally, our paper relates to the fast growing literature on NIRP and the reversal interest rate. The reversal interest rate is a concept developed by [Brunnermeier and Koby, 2018], indicating that accommodative monetary policy can turn contractionary and reduce lending. The theoretical literature has analysed several transmission mechanisms of NIRP, affecting the reversal rate: banks' profits ([Ulate, 2021] and [Eggertsson et al., 2019]), banks' capitalisation ([Darracq Pariès et al., 2020]) and central bank signalling ([Sims and Wu, 2020] and [de Groot and Haas, 2022]). However, little is known about the transmission of NIRP and the implication for the reversal rate when the dual rate strategy is implemented: this monetary policy strategy is analysed empirically only in the recent ECB study by [Barbiero et al., 2022]. Our paper fills this gap from a theoretical perspective.

3 Model

This paper takes the tractable DSGE model of UMP developed by [Sims and Wu, 2020] as a baseline. We extend it by micro-founding the liquidity injections, modelling them in the spirit of the ECB TLTRO during the Covid-19 crisis. The main changes to the baseline are the following:

- **On the financial intermediary's side**, the possibility to access the central bank lending programme, subject to a collateral constraint;
- **On the central bank's side**, the possibility to lend to intermediaries — while deploying QE, NIRP and FG. Mirroring the most recent TLTRO recalibration of March 2020, the central bank toolkit is expanded with the three instruments described in subsection 1.2:
    1. The collateral's haircut,
    2. The choice on the assets eligible for collaterals, and
    3. The rate applied to the liquidity provisions

Having realistically micro-founded the lending programme, we explore the synergies and trade-offs between the liquidity provisions and the other UMP tools.

There are multiple agents in the model: 1) a representative household; 2) a labour market; 3) a capital goods producing firm; 4) a representative wholesale firm; 5) a continuum of retail firms, that sell wholesale output to a final good firm; 6) a fixed number of financial intermediaries; 7) a fiscal authority; 8) and the central bank conducting monetary policy. In the subsections below we present financial intermediaries and the central bank: the two agents that differ from the baseline model.

3.1 Financial intermediary

Using the banking sector of [Sims and Wu, 2020] as baseline, the paper introduces the lending facility as in [Quint and Tristani, 2018]. The banking sector's balance sheet is the following:

$$Q_t F_t + Q_{B,t} B_t + RE_t = N_t + D_t + H_t \tag{1}$$

.

where $Q_t F_t$ are long term bonds issued by a representative wholesale firm, $Q_{B,t} B_t$ are long term bonds issued by the fiscal authority, RE_t are interest-bearing reserves, N_t is net worth, D_t are deposits taken from households, H_t is the central bank liquidity injection. Net worth evolves according to:

$$N_t = (R_t^F - R_{t-1}^d) Q_{t-1} F_{t-1} + (R_t^B - R_{t-1}^d) Q_{B,t-1} B_{t-1} + (R_{t-1}^{re} - R_{t-1}^d) RE_{t-1} + R_{t-1}^d N_{t-1} - (R_{t-1}^H - R_{t-1}^d) H_{t-1} \tag{2}$$

R^{re} is the (gross) interest rate on reserves, set by the monetary authority at $t-1$. R^d and R^H are, respectively, the deposit rate and the rate to access the central bank lending programme. R_t^F and R_t^B are the realised holding period returns on private and government bonds.

The financial intermediary maximises the expected value of terminal net worth. There is a $1-\sigma$ probability that it will exit after $t+1$, a $(1-\sigma)\sigma$ probability that it will exit after $t+2$, and so on. Accordingly, the bank's objective is:

$$V_{i,t} = max(1-\sigma) E_t \sum_{j=1}^{\infty} \sigma^{j-1} \Lambda_{t,t+j} n_{i,t+j} \tag{3}$$

3.1.1 Financial Intermediary's Constraints

The financial intermediary faces three constraints: the agency problem à la [Gertler and Kiyotaki, 2010], the reserve requirement as in [Sims and Wu, 2020] and the collateral constraint à la [Kiyotaki and Moore, 1997].

1. **Enforcement constraint** We impose a constraint on the availability of funds [Gertler and Kiyotaki, 2010] by allowing a financial intermediary to run away with some assets at the end of a period. If the intermediary absconds with assets, it defaults on its debt and it shuts down. Depositors, left with the remaining fraction of the intermediary's assets, become less willing to fund the intermediary, triggering a borrowing constraint. With less funding, the intermediary can fund fewer asset purchases, causing higher excess returns. We model this friction following [Quint and Tristani,

2018]: we impose that the financial intermediary maximizes terminal net worth subject to the following enforcement constraint:

$$V_t \geq \theta(Q_t f_t + \Delta Q_{B,t} b_t - \zeta h_t) \tag{4}$$

According to the above incentive constraint, depositors will continue to fund an intermediary as long as the intermediary's value V_t is at least as large as the gain it would make by running away with assets. If an intermediary absconds with assets, it keeps the fractions θ of corporate bonds, $\theta\Delta$ of government bonds and $\theta\zeta$ of the central bank liquidity provisions. As in [Gertler and Karadi, 2013], we set $0 \leq \Delta \leq 1$, hence it is easier to run away with corporate bonds than government bonds. As in [Quint and Tristani, 2018], we calibrate $\zeta = 1$: banks cannot divert assets financed by the liquidity provision of the central bank.

Finally, θ represents a credit shock: as θ increases, depositors are able to recover a smaller fraction of the intermediary's assets. Hence depositors reduce lending, creating a borrowing constraint for the intermediary. As intermediation breaks down, the demand for bonds weakens, triggering a fall in assets' value and widening interest rate spreads — dynamics observed in a variety of credit shocks, from the Global Financial Crisis to the "Dash for Cash" of March 2020. As in [Sims and Wu, 2020] we keep θ stochastic, following an exogenous AR(1) process:

$$\theta = (1 - \rho_t)\theta_{SS} + \rho_t \theta_{t-1} + s_t \epsilon_t \tag{5}$$

The central bank lending programme works in the opposite direction of a rise in θ: as the central bank injections increase, the enforcement constraint is eased and the intermediary can purchase more assets, thus supporting assets' prices and investment. This mechanism represents the liquidity channel of section 1.3.

2. **Reserve requirement constraint** As in [Sims and Wu, 2020], intermediaries are required to hold a minimum level of reserves that is set by the central bank. The reserve requirement is time-varying and proportional to an intermediary's deposits:

$$re_{i,t} \geq \xi d_{i,t} \tag{6}$$

The reserve requirement constraint is included to allow the central bank to engage in NIRP: if the model did not include this requirement, intermediaries would liquidate their negative-yielding reserves, preventing NIRP from being implemented.

3. **Collateral constraint.** The provision of central bank's liquidity is based on eligible collateral. The central bank decides on the quantity (haircut) and quality (asset class) of the collateral. To model these features we

include a collateral constraint in the spirit of [Kiyotaki and Moore, 1997] and [Iacoviello, 2005]. Following [Furkan Abbasglu et al., 2019], the liquidity injection h_t that the financial intermediary receives is constrained by a fraction $\kappa_{b,t}$ of its government bond holdings and a fraction $\kappa_{f,t}$ of its corporate bond holdings:

$$h_t \leq \kappa_{f,t}\frac{Q_{F,t}f_t}{R_t^H} + \kappa_{b,t}\frac{Q_{B,t}b_t}{R_t^H} \tag{7}$$

As in [Furkan Abbasglu et al., 2019], the collateral constraint is always binding: this is to ensure the central bank can effectively steer market rates by changing collateral policies setting the haircuts ($\kappa_{b,t}$ and $\kappa_{f,t}$) and by deciding the class of eligible assets (sovereign or corporate bonds). Initially, we keep $\kappa_{b,t}$ and $\kappa_{f,t}$ stochastic, following an exogenous AR1 process (the endogenous cases will be analysed in subsection 5.3):

$$\kappa_{b,t} = (1-\rho_{b,k})k_{b,ss} + \rho_{b,k}k_{b,t-1} + s_k\epsilon b, k \tag{8}$$

$$\kappa_{f,t} = (1-\rho_{f,k})k_{f,ss} + \rho_{f,k}k_{f,t-1} + s_k\epsilon f, k \tag{9}$$

The inclusion of this constraint has two implications. First, shocks are amplified relative to the baseline model: in fact, when a shock hits the economy, it is propagated not only due to the enforcement constraint (already present in [Sims and Wu, 2020]), but also due to the changes in value of the collateral. Second, the central bank's toolbox is expanded: policymakers can now use effectively collateral policy, triggering the collateral channel of monetary policy transmission (see section 1.3).

FOCs The paper maximises with respect to f_t, b_t, re_t and h_t. The FOCs are:

$$E_t\Lambda_{t,t+1}(R_{t+1}^F - R_t^d)\pi_{t+1}^{-1}\Omega_{t+1} = \frac{\lambda_{1,t}}{1+\lambda_{1,t}}\theta - \frac{1}{R_t^H}\frac{\lambda_{3,t}}{1+\lambda_{1,t}}\kappa_{f,t} \tag{10}$$

$$E_t\Lambda_{t,t+1}(R_{t+1}^B - R_t^d)\pi_{t+1}^{-1}\Omega_{t+1} = \Delta\frac{\lambda_{1,t}}{1+\lambda_{1,t}}\theta - \frac{1}{R_t^H}\frac{\lambda_{3,t}}{1+\lambda_{1,t}}\kappa_{b,t} \tag{11}$$

$$E_t\Lambda_{t,t+1}(R_t^{re} - R_t^d)\pi_{t+1}^{-1}\Omega_{t+1} = -\frac{\lambda_{2,t}}{1+\lambda_{1,t}} \tag{12}$$

$$E_t\Lambda_{t,t+1}(R_t^H - R_t^d)\pi_{t+1}^{-1}\Omega_{t+1} = \zeta\frac{\lambda_{1,t}}{1+\lambda_{1,t}}\theta - \frac{\lambda_{3,t}}{1+\lambda_{1,t}} \tag{13}$$

With $\Omega^h = 1-\sigma+\sigma\frac{\partial V_{1,t+1}}{\partial n_{1,t+1}}$. $\lambda_{1,t}$ is the Lagrangian multiplier of the enforcement constraint, $\lambda_{2,t}$ is the Lagrangian multiplier of the reserve requirement and $\lambda_{3,t}$ is the Lagrangian multiplier of the collateral constraint (always binding).

3.2 The Central Bank

The central bank is modelled following [Sims and Wu, 2020]. This paper adds to the unconventional monetary policy toolbox a lending facility with the same characteristics of the ECB TLTROs. This addition provides the central bank with three additional degrees of policy freedom,[20] the ability to lower banks' funding costs directly — a unique property of the liquidity provisions, distinctive from the other monetary tools — and the possibility to create synergies with the other UMP instruments.

3.2.1 Conventional Monetary Policy

The central bank sets the short-term policy rate R_t^{tr} according to the following Taylor rule:

$$lnR_t^{tr} = (1-\rho_r)lnR^{tr}+\rho_r lnR_{t-1}^{tr}+(1-\rho_r)[\phi_\pi(ln\Pi_t-ln\Pi)+\phi_y(lnY_t-lnY_{t-1})]+s_r\epsilon_{r,t} \tag{14}$$

With R^{tr} and Π being steady state values of the policy rate and the inflation target. In standard times, the central bank sets the interest rate on reserves equal to the underlying policy rate R_t^{tr}, and the reserve requirement is not binding:

$$R_t^{tr} = R_t^d = R_t^{re} \tag{15}$$

To implement the zero lower bound (ZLB), we impose that the deposit rate and interest rate on reserves are equal in the following way:

$$R_t^d = R_t^{re} = max(1, R_t^{tr}) \tag{16}$$

3.2.2 Unconventional Monetary Policy: the Lending Programmes

The baseline model features QE, NIRP and FG.[21] While these three UMP tools are still present in our model, this subsection explains the modelling of the central bank liquidity injections, that the paper introduces mirroring the ECB TLTROs.

With the lending programme, the central bank gains three additional degrees of policy freedom. In fact, it can change the collateral policy — through the haircut and set of assets eligible for collateral — as well as the interest rate it charges on its loans. By setting these policy tools, the central bank may choose to tighten or ease the access to its lending facility, affecting bank financing conditions for households and firms.

- **Collateral Policy.** The central bank decides on:

[20] The central bank can set i) the collateral's haircut, ii) the assets eligible for collaterals, and iii) the rate applied to the liquidity provisions.

[21] For details on their implementation see [Sims and Wu, 2020].

- The *quantity* of collateral (haircut) by changing $\kappa_{b,t}$ and $\kappa_{f,t}$.
- The *quality* of the collateral, by deciding whether to accept only sovereign bonds ($\kappa_{f,t} = 0$), only corporate bonds ($\kappa_{b,t} = 0$) or a mix of sovereign and corporate bonds.

The paper makes the collateral policy endogenous by imposing Taylor rules for $\kappa_{b,t}$ and $\kappa_{f,t}$ (see subsection 5.3).

- **Interest Rate on loans — "dual rate system".** When the ZLB constraint is not binding, the interest rate on the liquidity injection is imposed to be equal to the interest rate on reserves (policy rate): this modelling choice ensures the "favourable terms" of the ECB TLTROs. Instead, when the ZLB constraint is binding and the central bank engages in NIRP, the rate falls below the policy rate. In other words:

$$R_t^h = R_t^{re} - \chi_t \tag{17}$$

Where R_t^h is the interest rate on the lending facility, R_t^{re} is the rate on reserves and χ_t is a spread. When the ZLB constraint is not binding $\chi_t = 0$, when instead the ZLB constraint is binding, χ_t is governed by the following Taylor rule (in the spirit of equation 14 governing the policy rate):

$$\chi_t = (1-\rho_\chi)\chi_{ss}+\rho_\chi\chi_{t-1}-\eta_\chi(1-\rho_\chi)[\phi_\pi(ln\Pi_t-ln\Pi)+\phi_y(lnY_t-lnY_{t-1})]+s_\chi\epsilon_{\chi,t} \tag{18}$$

Given the occasionally binding constraint, this paper uses the Occbin toolkit developed by [Guerrieri and Iacoviello, 2015] to shift from one regime to the other.[22]

4 Calibration

Most of the parameters in the model have standard values. The non-standard parameters — associated with the financial sector — have been taken from [Sims and Wu, 2020] and [Quint and Tristani, 2018]. The parameters referring to the lending programmes are listed in Table 1 below. Amongst these, we focus on the calibration of those governing the collaterals. At the steady state $\kappa_{f,ss}$ is calibrated equal to zero: this is because at the steady state there are not liquidity

[22] As in [Sims and Wu, 2020], anytime the Taylor rule rate goes below the steady state interest rate on reserves (making the ZLB constraint binding), the toolkit switches to a different model in which we impose the rate on reserves equal to 0. In this model, the deposit rate equals the interest rate on reserves and the central bank can use collateral policy. Differently, in the case of NIRP implementation, when the Taylor rule rate goes below the steady state interest rate on reserves, the Occbin toolbox switches to a model in which the interest rate on reserves follows the (now negative) Taylor rule rate but the deposit rate remains stuck at 0.

injections that need corporate bond as collaterals. Instead, the paper calibrates $\kappa_{b,ss}$ at 0.1. This implies that at steady state the lending programmes (for which sovereign bonds are required as collaterals) are still active. We motivate this modelling choice by observing that in March 2019 the ECB introduced the third round of TLTROs to avoid "congestion effects"in bank funding markets that would have otherwise materialised because of the need to replace expiring TLTRO II funds[Barbiero et al., 2021].

Table 1: New Calibrated Parameters

Parameter	Value or Target	Description
$\kappa_{b,ss}$	0.1	CB Steady State Fraction of sovereign bond collaterals
$\kappa_{f,ss}$	0	CB Steady State Fraction of corporate bond collaterals
ζ	1	Central bank loans recoverability
χ	0	Steady state spread $R_t^{re} - R_t^h$
$\rho_{b,k}$	0.8	AR sovereign bond collateral
$\rho_{f,k}$	0.8	AR corporate bond collateral
ρ_{χ}	0.98	AR spread $R_t^{re} - R_t^h$

5 Simulations above the ZLB: Exploring the transmission channels

This section presents simulations when the ZLB constraint is not binding. The simulations are useful to understand the mechanics of the model and to explore the transmission channels of the "enhanced" lending programme's, explained in section 1.3: i) liquidity channel, ii) collateral channel (working through the haircut, asset class eligible for collateral and the value of the collateral), iii) the "dual rate channel", and iv) scarcity channel. This analysis informs the policy simulations of the following section 6, allowing to discover synergies and trade-offs amongst the different UMP tools.

5.1 Liquidity Channel

Figure 2 below shows the IRFs to a one standard deviation positive shock to $\kappa_{b,t}$ in equation 8. $\kappa_{b,t}$ is the variable governing the sovereign bond collateral accepted by the central bank's lending programme (the haircut). Output, investment and inflation accelerate, the bonds spreads are compressed and the net worth of the financial intermediary increases. Looking at the central bank's monetary tools, liquidity injections grow and the policy rate is higher. The reason for these dynamics is the following. As the central bank accepts a higher fraction of the value of the sovereign bonds held by the financial intermediary, the liquidity injections increase following equation 7. The higher liquidity injections ease the intermediary's incentive constraint (liquidity channel) as per equation 4, allowing more bond purchases. The higher demand for bonds

compresses bond spreads, easing the wholesale firm's constraint[23] and fuelling investment and output. In addition, the higher asset value (lower spreads) increases the intermediary's net worth (equation 2), further allowing more bond purchases and supporting output. The policy rate is hiked following the Taylor rule as in equation 14.

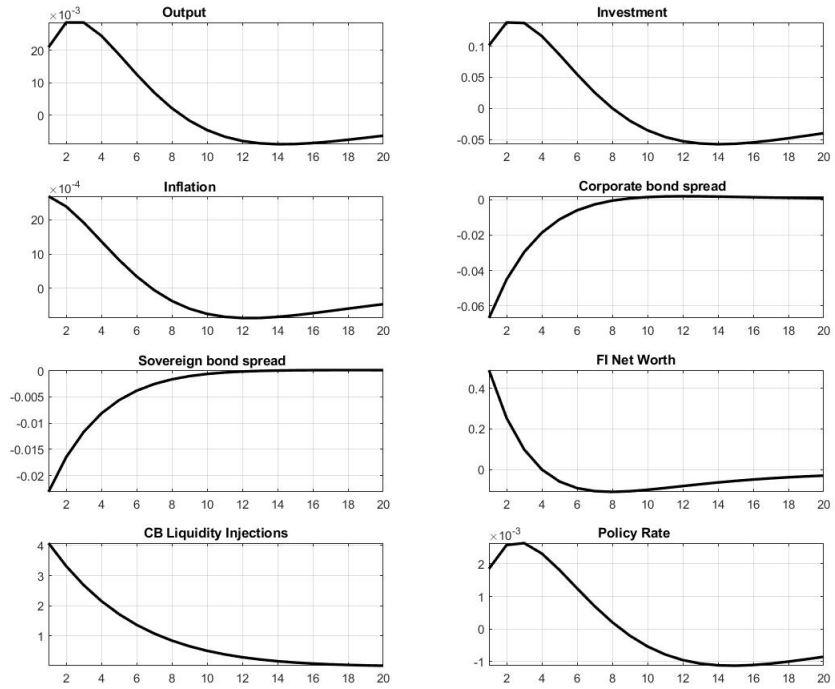


Figure 2: Sovereign bond haircut shock ($\kappa_{b,t}$ shock)

5.2 Collateral Channel

5.2.1 Collateral policy: haircut and asset class eligible for collateral

Figure 3 shows the IRFs to a credit shock, without the lending programme (black solid line) and with the lending programme (red dotted line). To have the central bank reacting to the shock changing its collateral policy we make $\kappa_{b,t}$ and $\kappa_{f,t}$ endogenous. In particular, we impose that the central bank increases the *quantity* (haircut) and *quality* (eligible asset class) of the collateral it accepts

[23] For more details on the modelling of the wholesale firm, please see [Sims and Wu, 2020].

according to the following Taylor rules:[24]

$$\kappa_{b,t} = (1-\rho_{b,k})k_{b,ss}+\rho_{b,k}k_{b,t-1}-\eta_{b,k}(1-\rho_{b,k})[\phi_{b,k}(ln\Pi_t-ln\Pi)+\phi_{b,k}(lnY_t-lnY_{t-1})]+s_{b,k}\epsilon_{b,k,t} \tag{19}$$

$$\kappa_{f,t} = (1-\rho_{f,k})k_{f,ss}+\rho_{f,k}k_{f,t-1}-\eta_{f,k}(1-\rho_{f,k})[\phi_{f,k}(ln\Pi_t-ln\Pi)+\phi_{f,k}(lnY_t-lnY_{t-1})]+s_{f,k}\epsilon_{f,k,t} \tag{20}$$

As a result, when the shock hits the economy, there is collateral easing by the central bank that increases the liquidity injections by 9% (see IRF below called CB Liquidity Injections). As a result of the central bank loans, the intermediary's constraint is looser, hence the demand for bonds is higher, which pushes up the prices of bonds, similarly to the previous simulation. The higher bonds' price allows more investment by the firm, dampening the recession. Overall, easing the collateral rules allows more liquidity injections and it helps to stabilise output.

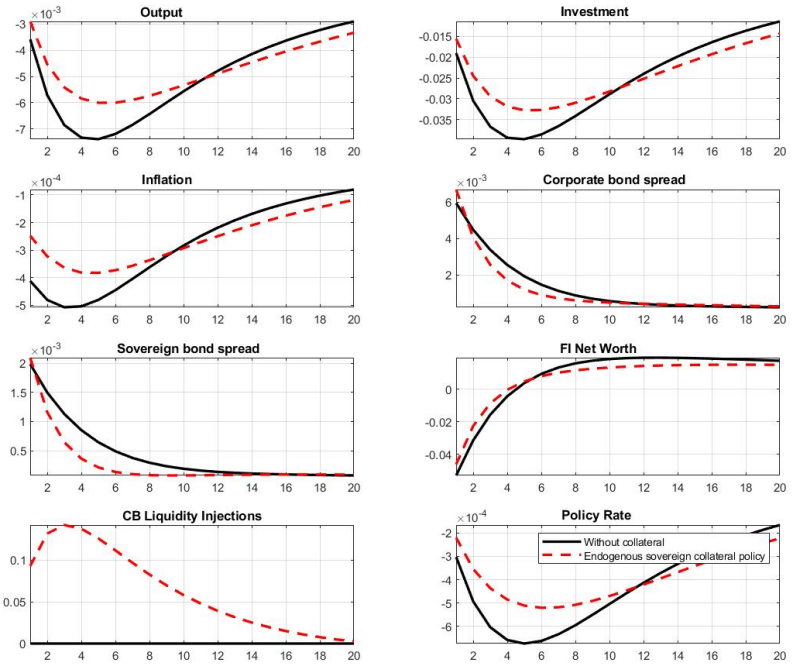


Figure 3: Credit shock, with and without endogenous collateral policy

[24]Equation 19 and 20 follow the methodology used by [Sims and Wu, 2020] to make QE endogenous. For this, we assume that the central bank's reaction function to inflation and output (represented by the parameters in equations 19 and 20) is the same for QE and the lending programme

5.2.2 Collateral policy: asset value

Figure 4 shows the IRFs to a sovereign bond QE shock,[25]without any collateral (black solid line) and with corporate bonds as collateral (red dotted line). QE is modelled as central bank's purchases of sovereign bonds financed through the issuance of reserves held by banks. QE has real effects because it eases the constraint by changing the composition of banks' assets. In other words, the central bank swaps bonds for reserves: in doing so, it swaps assets that are not perfectly recoverable in case of bank default (bonds) with assets that are perfectly recoverable (reserves), easing the constraint (see the baseline model of [Sims and Wu, 2020]). In this simulation the central bank engages only in sovereign bond purchases. At steady state corporate bonds are required as collateral — implying that at steady state there are liquidity injections — but policymakers do not engage in collateral easing[26] We notice that the use of collateral leads to an amplification of the expansionary effect of QE. This not an unexpected but important result to establish. The reason for the amplification mechanism is the following. As the central bank purchases sovereign bonds, it swaps them with reserves, easing the constraint of the intermediary (equation 4) that can now increase its demand for sovereign and corporate bonds, putting upwards pressure on their prices and compressing their spreads. The result is that, even if the central bank purchases only sovereign bonds, ultimately, thanks to the portfolio rebalancing channel of QE [Albertazzi et al., 2021], the price of corporate bonds increases as well. In other words, corporate bond spreads are compressed further: see the IRF below titled Corporate bond spread. The higher corporate bond value allows the wholesale firm to invest more but, critically, it *also* translates into higher collateral value (as per equation 7), allowing the intermediary to access more liquidity from the central bank. This loosens further the intermediary constraint, putting upwards pressure on bonds' prices and fuelling output. Overall, this simulation shows that there is an important synergy between between QE and lending programme. In section 6 this synergy is applied to policy experiments.

[25]Since central bank bond holdings follow exogenous AR(1) processes (see [Sims and Wu, 2020]), we can use them to simulate a QE shock.

[26]This implies that collateral policy is not endogenous: $\kappa_{b,t}$ and $\kappa_{f,t}$ do not follow equations 19 and 20, instead they are set exogenously according to equations 8 and 9.

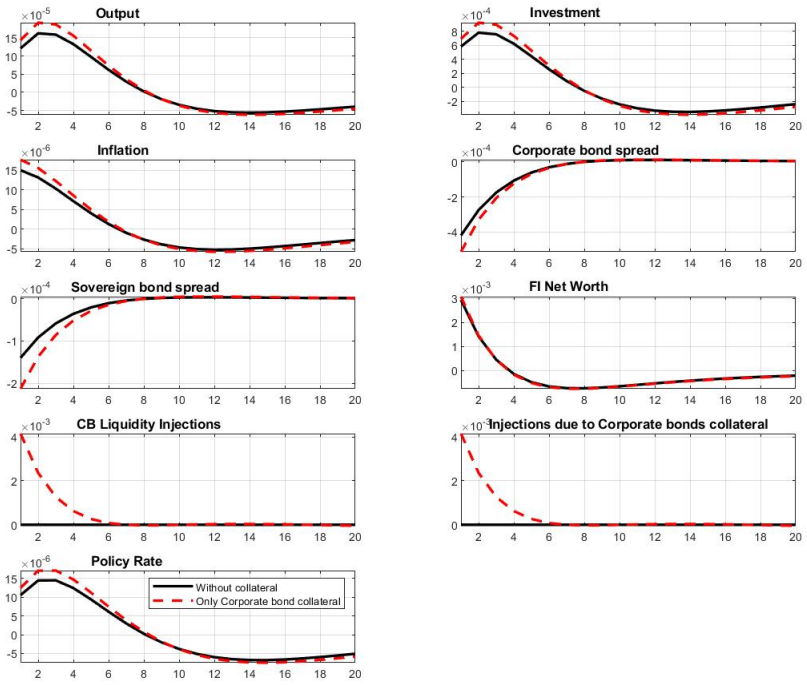


Figure 4: QE government bonds shock, with and without collateral policy (corporate bond)

5.3 Scarcity channel

Figure 5 shows the IRFs to a sovereign bond QE shock, without any collateral (black solid line) and with sovereign bonds as collateral (red dotted line). As in the previous simulation, the central bank engages only in sovereign bond purchases, it does not use any other UMP tool. However, different from the previous case, at steady state it requires financial intermediaries to hold sovereign bonds (not corporate bonds as was the case in the previous sub-section) as collateral. The supply of sovereign bonds is calibrated: as in [Sims and Wu, 2020], at steady state the debt-to-GDP ratio is fixed at 41%. We notice that the use of collateral leads to a weaker expansion. The reason for this is the following. If the central bank decides to purchase sovereign bonds and at the same time to accept sovereign bonds for the liquidity injections, there will be a scarcity of sovereign bonds for the financial intermediary to hold. This is signalled by the lower steady state interest rate on sovereign bonds, determined endogenously.[27]

[27]The interest rate on sovereign bonds without the collateral requirement is 3%, while it is 2.4% when the central bank requires sovereign bonds to be pledged as collateral.

Lower interest rates are a hallmark of the scarcity channel [Grandia et al., 2019]. At the same time, having sold sovereign bonds to the central bank, now the intermediary has less sovereign bonds to access the lending programme: the liquidity injection falls by 1.5%, tightening the intermediary's constraint and dampening the expansion. Overall, the pent-up demand for assets generated by the central bank gives rise to a scarcity of available assets, thus forming a contractionary channel that weakens the monetary stimulus. This simulation highlights the importance of *coordinating* monetary policy through the different UMP tools since their simultaneous delivery can amplify (see previous simulations) as well as weaken the effectiveness of monetary policy interventions.[28].

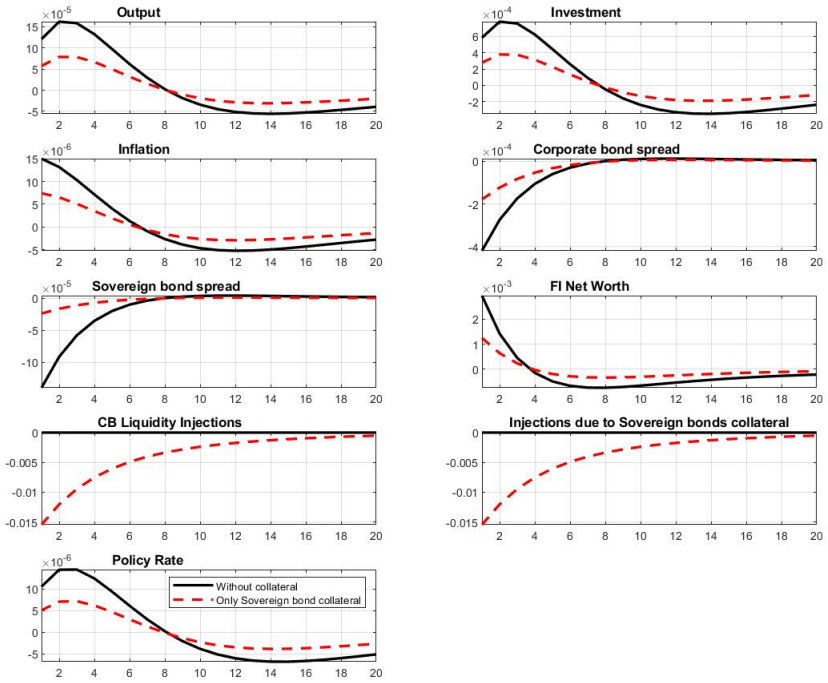


Figure 5: QE government bonds shock, with and without collateral policy (sovereign bond)

[28]The importance of complementarities between instruments was highlighted, amongst the others, by Bank of England External MPC Member [Saunders, 2020] when looking at monetary policy options with a binding ZLB (during the Covid-19 pandemic). Another topic for future work is the timing of the delivery of the different UMP tools.

5.4 The Dual Rate channel

Figure 6 shows a one standard deviation shock to the spread between interest rate on reserves and the interest rate on the central bank's loan (see equations 17 and 18). The shock creates the "dual rate system" (see the IRF below titled "Rate Reserve - Rate Injections"). The IRFs show that output, investment and inflation accelerate. The bonds'spreads are compressed while the intermediary's net worth accelerates. Finally, as the spread between interest rate on reserves and interest rate on central bank's loan widens, the liquidity injections increase (see IRF titled CB liquidity Injections) and the policy rate is hiked following the Taylor rule. The reason for these movements is the following: Having the interest on the lending programme lower than the interest on reserve is similar to having a subsidy on net worth (equation 2), hence the financial intermediary accumulates net worth. In addition, the loans from the central bank now are offered at a discount, hence the intermediary will be more willing to access the lending programme. The resulting higher liquidity injections and higher net worth ease the enforcement constraint of the intermediary (equation 4), which increases the demand for bonds. This puts downward pressure on bonds' yields, compressing spreads, easing the constraint of the wholesale firm and supporting investment. The policy rate is hiked following the Taylor rule as per equation 14. Overall, lowering the intermediary's funding costs without cutting the policy rate is an effective measure to fuel output. In the next section we will study the interaction with NIRP.

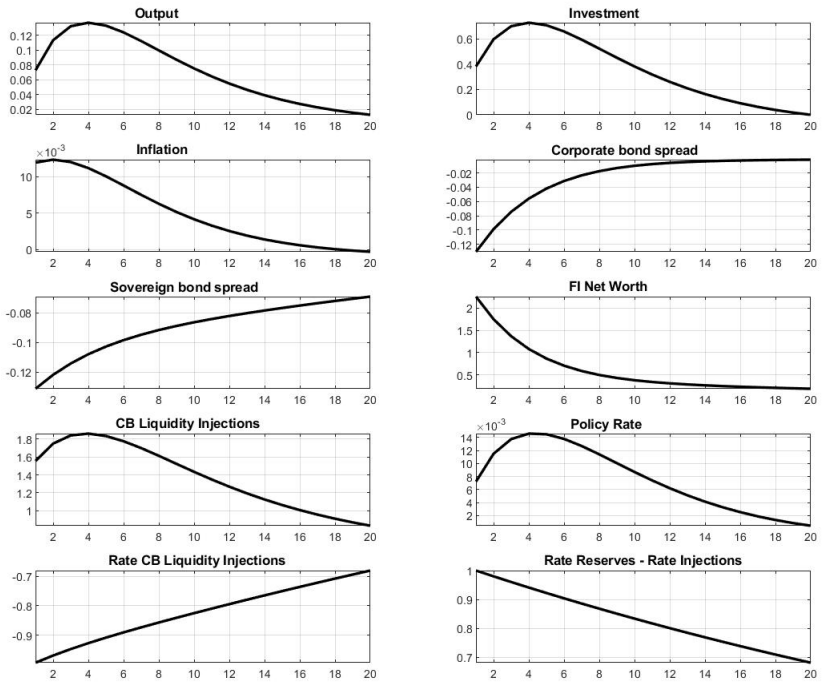


Figure 6: Dual rate shock

6 Simulations at ZLB: Policy experiments

This section uses the above described model to analyse the effects of different monetary policies when different tools are utilised on their own and/or in unison with others. This time at the ZLB. The aim here is to disentangle transmission channels, to detect strengths and weaknesses of each policy or combinations of policies between QE, NIRP and lending programmes. We do this by looking at seven different sets of policy simulations. We find that the synergies between the lending programmes and the other UMP instruments make three cases for their simultaneous deployment:

1. When the lending programmes are deployed **simultaneously with QE**, synergies — working through the collateral value — and trade-offs — generated by the scarcity of available assets — arise. By setting its collateral policy, the Central Bank can strengthen the positive interactions and overcome the trade-offs, improving monetary policy effectiveness.

2. When the lending programmes are deployed **simultaneously with NIRP**,

the dual rate system supports financial intermediaries' net worth. This synergy prevents the economy from hitting the reversal interest rate, again increasing monetary policy effectiveness.

3. Finally, once the economy is in recovery, the smooth, complete, **simultaneous unwinding** of both QE and the lending programme ensures the most effective normalisation policy.

We draw the above policy conclusions from simulating the following seven experiments:

1. **Exogenous Unconventional Monetary Policy Shocks**. This set of policy experiments assesses the effectiveness of the monetary tools governing the lending programmes — collateral policy and dual rate strategy — relative to the three other UMP tools: QE, NIRP and FG. To do this, we run eight monetary policy shocks. [29] By comparing the IRFs, the paper finds that, if the objective is to find an alternative policy to QE to support aggregate demand when the economy hits the ZLB, then the lending programmes offer another equally effective option. The section also provides guidelines on the timing of the policy delivery: the dual rate policy should be deployed only after easing collateral policy.

2. **Exogenous QE and exogenous lending programmes: Synergies and trade-offs** The previous section compared the effectiveness of the lending programmes relative to the other UMP tools when they are delivered *in isolation*. This section, instead, takes stock of recent policy experience during the Covid-19 crisis, and it allows QE and the lending programmes to be delivered *simultaneously*. This is critical to explore the interactions, synergies and trade-off between the monetary instruments, the aim of the paper. The section finds that UMP effectiveness is amplified if the value of the collateral benefits from the portfolio rebalancing effect of QE (synergy). However UMP can also be weakened if the availability of the collateral worsens due to asset purchases (trade-off).

3. **Endogenous QE and endogenous lending programmes** The previous simulations study the interactions generated by a QE shock with the lending facility assuming that the central bank does not actively use collateral policy while it is engaging in asset purchases. In other words, the liquidity channel of the lending programme is not activated. Policy experience shows that this is an unrealistic simplification. To reflect policymakers' choices, this subsection makes both QE and the lending programme endogenous in response to a credit shock, introducing the liquidity channel in the simulation and running two policy experiments:

[29] The exogenous monetary shocks are: Three shocks to the lending programme, representing collateral policy easing and the dual rate strategy, a conventional monetary policy shock, a sovereign bond asset purchases (QE) shock, a corporate bond asset purchases (QE) shock, a FG shock and a NIRP shock.

- **Lending programme - QE: Trade-off.** Given that the scarcity channel and the liquidity channel have opposite effects, the aim of this subsection is to assess their net effect. We show that the expansionary liquidity channel — generated by endogenising the collateral policy — overcomes the contractionary scarcity channel — generated by the central bank's pent-up demand for sovereign bonds. From a policy perspective, this suggests that the most effective framework to respond to a credit crisis is a combination of sovereign bond purchases and lower haircut on sovereign bonds.
- **Lending programme - QE: Synergy.** The portfolio rebalancing channel of QE and the liquidity channel of the lending facility work in unison by easing the intermediary enforcement constraint. This section shows that by engaging in both QE and collateral policy, liquidity injections benefit from QE, allowing the central bank to achieve a higher degree of output stabilisation with a smaller balance sheet intervention.

4. **Endogenous NIRP and endogenous lending programmes: the dual rate.** So far the paper has explored the interactions between QE and the lending programme. This set of policy simulations explores the synergies between NIRP and the lending programme, taking stock of the ECB experience: The dual rate policy, in fact, is implemented when the policy rate is already set negative. To model the ECB decisions this section simulates a credit shock to which the central bank reacts by i) engaging in NIRP, ii) setting the rate on the lending programme *endogenously* below the policy rate, and iii) setting *endogenously* the collateral haircut. We find that the synergies between these tools ensure a higher degree of output stabilisation and prevent the reversal of the interest rate.

5. **Policy Normalisation: Choosing the Tightening Pace and Combination of Instruments** Having explored the synergies and trade-off arising when the lending programmes are deployed simultaneously with other tools, we now analyse the interactions when the unconventional tools are withdrawn. This set of policy experiments study the effects on output and central bank balance sheet of different tightening pace and combinations of QE/lending programmes. Currently, the knowledge on the exit from UMP is limited, leaving "policymakers uncertain about the effects of their policy on the economy"[Panetta, 2022b]. We find that the most effective strategy is a smooth and complete unwinding of both QE and the lending programme. If this was not possible, QE should be exited quickly and the lending programme carried forward.

6.1 Exogenous Unconventional Monetary Policy Shocks

The aim of this section is to assess the effectiveness of the monetary tools governing the lending programmes — collateral policy and dual rate strategy —

relative to the three other UMP tools: QE, NIRP and FG. To do this, the paper first makes the ZLB constraint binding: this is necessary because UMP is applied only when short term rates hit the effective lower bound.[30] The ZLB constraint dictates that the short-term Taylor rule rate R_t^{tr} cannot go below its steady state set at 1% in gross terms (this is the steady state interest rate on reserves).[31] Once the economy is at the ZLB, the paper assesses the effectiveness of the different monetary tools. Figure 7 below compares the IRFs to eight different monetary policy shocks: three shocks to the lending programme — representing sovereign bond collateral easing (light blue dotted line), corporate bond collateral easing (red dotted line) and dual rate policy easing (dark blue dotted line) — a policy rate shock (solid blue line), a corporate bond QE shock (orange dotted line), a sovereign bond QE shock (yellow dotted line), a NIRP shock (green dotted dotted line) and finally a FG shock (purple dotted line). The shocks are calibrated to match the same increase in output given by the policy rate cut shock (0.49% in period nine).

First, we focus on the lending programme collateral easing shocks, that are shocks to $\kappa_{b,t}$ and $\kappa_{f,t}$ — respectively, the fractions (haircuts) of sovereign bonds and corporate bonds held by the intermediary that are accepted as collateral by the central bank. The transmission mechanism is the same as in section 5.1. We notice that the effectiveness of the liquidity injections is almost the same as corporate bond QE and higher than sovereign bond QE: output increases by 0.49% in all three cases but the central bank balance sheet increases by less than 4% of steady state output with liquidity injections and corporate bond QE while it increases by 14% with sovereign bond QE. The reason for this difference is the following. Purchasing corporate bond from an intermediary in exchange for reserves and increasing its loans from the central bank ease the intermediary's constraint by the same amount (see the incentive constraint in equation 4). But, since we assume that an intermediary would find harder to abscond with sovereign bonds than with corporate bonds — a canonical assumption in the literature, see [Gertler and Karadi, 2013] that finds empirical evidence in [D'Amico and Kaminska, 2019] — it takes more purchases of sovereign bonds to ease the constraint as much as in the other two cases.

Second, we focus on the lending programme dual rate shock. When the loans

[30] To achieve this, the paper follows [Sims and Wu, 2020] and it simulates credit shocks for 6 periods. Then it replicates the simulations but in the seventh period it simulates the monetary policy shock and then it takes the difference between the simulation with the additional monetary policy shock and the simulation without it, the resulting IRFs are presented in Figure 7 below. Output is deviation from the steady state in percentage terms; interest rates are in annualised percentage points; the central bank's balance sheet size is expressed relative to steady state output.

[31] To implement this occasionally binding constraint we use the Dynare Occbin toolkit developed by [Guerrieri and Iacoviello, 2015]: anytime the Taylor rule rate goes below the steady state interest rate on reserves (making the ZLB constraint binding), the toolkit switches to a different model in which we impose the rate on reserves equal to 0. In this model, the deposit rate equals the interest rate on reserves. Differently, in the case of NIRP implementation, when the Taylor rule rate goes below the steady state interest rate on reserves, the Occbin toolbox switches to a model in which the interest rate on reserves follows the (now negative) Taylor rule rate but the deposit rate remains stuck at 0.

from the central bank are limited to 10% of the sovereign bonds held by the intermediary (collateral), the interest rate on the lending programme must fall by more than 6% below the policy rate (stuck at 0%) for output to increase by 0.49%. This is not a policy that can be implemented but we notice (see Annex 1) that if the haircut on the collateral is eased (for instance to 30% of the sovereign bonds held by the intermediary), then the interest rate on the lending programme must fall by 2% below the policy rate (a significantly smaller fall than 6%) to lead to the same output acceleration as the other tools. This shows that our model is in line with policy decisions: the ECB lowered the interest rate on the lending programme to 1% below the policy rate when the share of sovereign *and* corporate bonds pledgeable as collateral was more than 30% of the portfolio holdings.

Overall, there are two takeaway messages from this section. First, liquidity injections are as effective as corporate bond QE and more effective than sovereign bonds QE in fuelling output. Given the political economy challenges posed by large programmes of corporate bond purchases,[32] the lending programmes offer an equally effective alternative to support aggregate demand when the economy hits the ZLB. Second, in order to maintain policy space (e.g. avoid large cuts to the interest rate on the lending programme), dual rate policy should not be deployed before easing the collateral policy.

[32]See the experience of the Bank of England Asset Purchase Facility Schemes: at the end of December 2021 it held GBP875 billion in Gilts and only GBP20 billion in corporate bonds

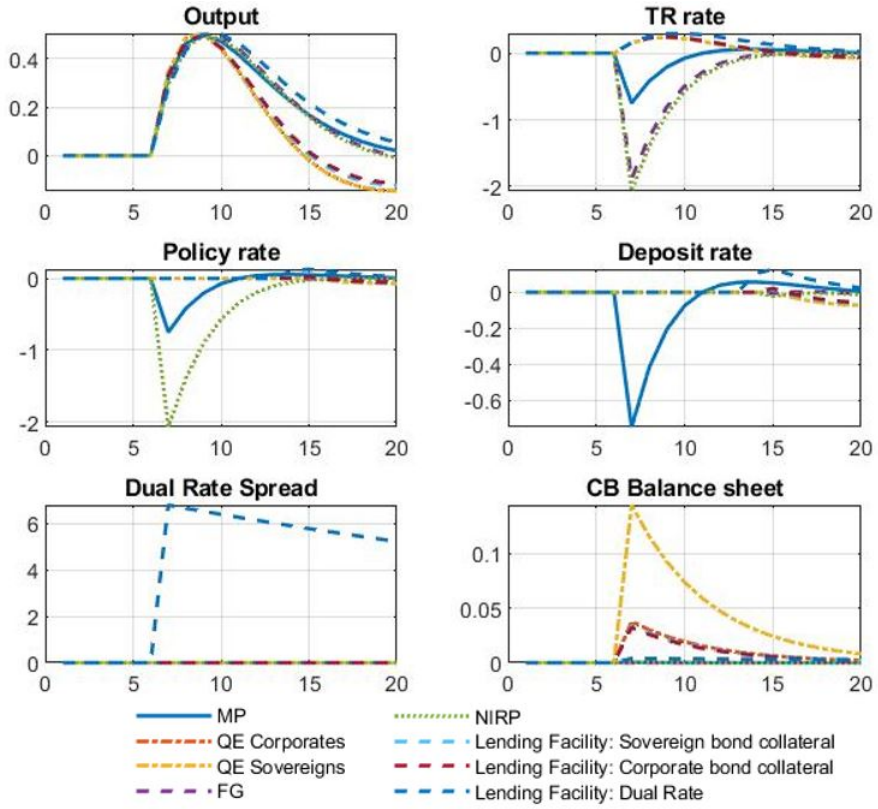
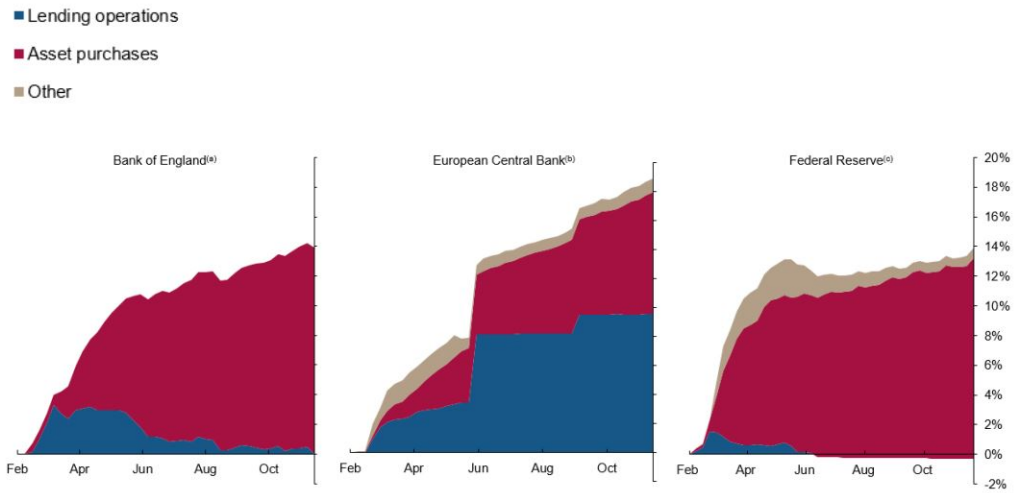


Figure 7: Monetary Policy Shocks

6.2 Exogenous QE and exogenous lending programmes: Synergies and trade-offs

The previous section compared the effectiveness of the lending programmes relative to the other UMP tools when the central bank deliver UMP tools *in isolation*. However, in reality, policymakers deploy UMP *simultaneously*, in particular the lending provisions are delivered in concert with QE programmes. Figure 8 below shows BoE, ECB and Federal Reserve balance sheet policies implemented in response to the Covid-19 pandemic, between February and December 2020. In the case of the ECB, the lending programmes have accounted for about half of the balance sheet increase, with the other half represented by asset purchases programmes [Hauser, 2021b]. This concerted strategy is reflected in policymakers' statement: [Schnabel, 2020a], member of the Executive Board of the ECB, highlighted that "three mutually reinforcing and complementary components" — QE, TLTRO with collateral policy and liquidity injections as lender of last resort — drove the ECB response to the pandemic. Taking stock of the most recent policy experience, this section studies the interactions

between QE and the lending programmes.



Sources: Bank of England, Bureau of Economic Analysis, European Central Bank, Eurostat, Federal Reserve Board, ONS and Bank calculations.

(a) Bank of England lending operations shown here: Indexed long-term repo, Contingent term repo facility, US dollar repo operations, Liquidity Facility in Euros, Term Funding Scheme and Term Funding Scheme with additional incentives for SMEs. Bank of England asset purchases shown here: Asset Purchase Facility and Covid Corporate Financing Facility.
(b) ECB lending operations: Lending to euro-area credit institutions related to monetary policy operations denominated in euro. ECB asset purchases: Securities held for monetary policy and other purposes.
(c) Federal Reserve lending operations: Repurchase agreements, Loans and Net portfolio holdings of TALF II LLC. Federal Reserve asset purchases: Securities held outright. Section of chart lying below the zero line from mid-2020 reflects a decline in repo outstanding relative to end-February.

Figure 8: Central bank balance sheet responses to the Covid-19 shock during 2020 — Changes in components of central bank balance sheets since end-Feb 2020 (as % of 2019 nominal GDP). Source: [Hauser, 2021b]

To document possible synergies and trade-offs between QE and lending programmes we first make the ZLB binding and then we simulate three QE shocks with and without the lending facility's collateral (at the steady state).[33] To be clear, the central bank engages only in asset purchases through its QE programmes, modelled as exogenous shocks. The liquidity injections are the mechanical result of the central bank's requirement at steady state to pledge assets as collateral — in other words, the central bank does not engage either in collateral policy or in dual rate policy. Figure 8 below shows the IRFs to the three positive shocks to the central bank's bond holdings.

Baseline model. The IRFs on the left-hand side represent the baseline simulations: at the steady state, there is no collateral requirement. The sovereign

[33]To achieve this, the paper follows the same methodology implemented in the previous simulation 6.1: first, it simulates credit shocks for 6 periods, pushing the economy to the ZLB; second, it replicates the simulations but in the seventh period it runs a QE shock; third, it takes the difference between the simulation with the additional QE shock and the simulation without it — the resulting IRFs are presented in Figure 9 below.

and corporate bond QE shocks have been calibrated to match the same output expansion: 0.53% growth in period nine.

Synergy. The charts in the centre shows IRFs to the same QE shocks that generated the left-hand side IRFs. The only difference is that at steady state we impose that the central bank requires corporate bond as collaterals (this implies that at steady state there are liquidity injections). An amplification mechanism is generated thanks to this collateral requirement: in fact, as the central bank purchases sovereign bonds with the QE programme, it not only increases the price of these assets but also indirectly increases the price of the corporate bonds (through the portfolio rebalancing effect). The value of the corporate bonds held by the intermediary is therefore higher and this allows more liquidity injections: the central bank balance sheet is larger when sovereign bond QE is accompanied with corporate bonds as collateral (on the LHS the central bank balance sheet's size is 12% of steady state output while it is 13% in the centre IRFs). Having access to more central bank's loans eases the constraint of the intermediary, fuelling aggregate demand: output accelerates by 0.64% (0.53% on the LHS). In short, the effectiveness of QE can be amplified by exploiting the portfolio rebalancing channel of QE and calibrating the collateral of the lending programme accordingly.

Trade-off. The IRFs on the right-hand side are generated by the same QE shocks that generated the left-hand side (baseline) IRFs. The only difference is that at steady state we impose that the central bank requires sovereign bond collaterals. This implies that there is a pent-up demand for sovereign bonds from the central bank, as it buys sovereign bonds through QE and it requires them for the lending programme. The scarcity channel arises: first, the higher demand for sovereign bonds compresses their spreads, hurting the net worth of the intermediary; second, the intermediary has less sovereign bonds to pledge as collateral after having sold them to the central bank, hence it will be able to access less loans. This can be seen from the size of the central bank balance sheet: when sovereign bond QE is accompanied by sovereign bond as collateral, the balance sheet is smaller (on the LHS the central bank balance sheet's size is 12% of steady state output while it is 10% on the RHS). With less loans from the central bank and smaller net worth, the expansionary effect of QE is weakened: output accelerates by 0.23% (0.53% on the LHS). Note that the corporate bond QE shock increases ouput relative to the baseline (collateral effect). Overall, through its unconventional operations the central bank can generate a scarcity of assets that can weaken the transmission of QE. Choosing strategically the collateral of the lending facility prevents the scarcity effect from arising.

Overall, we found that the effectiveness of UMP is amplified if QE and the lending programme are deployed in unison: in other words, the central bank delivers a larger output expansion if the value of the collateral is supported by the asset purchases, allowing more liquidity injections without using monetary policy space (no changes in haircut or in dual rate strategy). However, should the liquidity injections and QE generate a scarcity of available collateral, then the UMP tools will move in opposite directions, weakening the effectiveness of

the monetary stimulus.

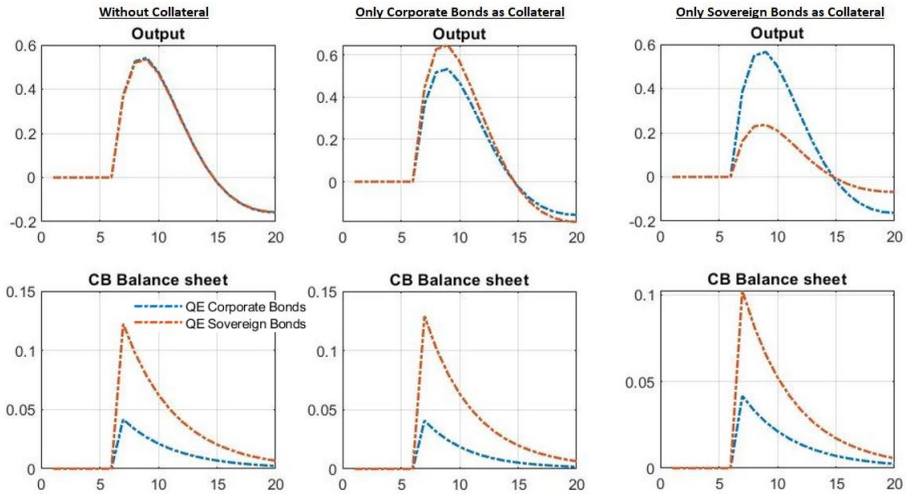


Figure 9: QE Shocks, with and without the lending programme's collateral

6.3 Endogenous QE and endogenous lending programmes

The previous subsection shows the interactions that a QE shock generates with the lending facility. In particular, it documents the rise of an amplification mechanism — working through the portfolio rebalancing channel of QE — and a weakening mechanism — triggered by the scarcity channel. However, the simulations in subsection 6.2 assume that the central bank does not use collateral policy while it is engaging in asset purchases. In other words, the liquidity channel of the lending programme is not activated. This is an unrealistic simplification because, in practice, QE and the lending programme are deployed *in unison* and *in response* to a macroeconomic shock. Indeed, member of the ECB Executive Board [Panetta, 2022a] states that the ECB has three main tools to adjust the monetary policy stance: the policy rate, QE and the lending programmes.

To reflect policymakers' choices, this subsection makes both QE and the lending programme endogenous in response to a credit shock. By endogenising the lending programme, we introduce the liquidity channel in the simulation. Given that the scarcity channel and the liquidity channel have opposite effects, the first aim of this subsection is to assess their net effect (paragraph 6.3.1). The second aim is to assess the extent to which the liquidity channel supports the rebalancing channel, as both channels enhance the effectiveness of monetary policy (paragraph 6.3.2).

To make QE endogenous, we follow [Sims and Wu, 2020] imposing that the central bank's sovereign bond holdings are set by the Taylor rule reaction function below:

$$b_{cb,t} = (1-\rho_b)b_{cb}+\rho_b b_{cb,t-1}+(1-\rho_b)\Psi_b[\Phi_\pi(ln\Pi_t-ln\Pi)+\Phi_y(lnY_t-lnY_{t-1})]+s_b\epsilon_{b,t} \tag{21}$$

In a similar fashion, the collateral policy is endogenised by imposing the following Taylor rules for $\kappa_{b,t}$ and $\kappa_{f,t}$ — the fractions of financial intermediaries' government and corporate bond holdings that can be pledged as collateral to the central bank's lending programme (e.g. haircuts). These reaction functions ensure that when output falls and inflation deviates from its steady state, the central bank engages in collateral policy easing (lower haircut on collaterals), prompting immediately more liquidity injections. The higher take-up of lending provisions eases the financial intermediary constraint (through the liquidity channel), fuelling more intermediation that supports asset prices as well as investment and output.

$$\kappa_{b,t} = (1-\rho_{b,k})k_{b,ss}+\rho_{b,k}k_{b,t-1}-\eta_{b,k}(1-\rho_{b,k})[\Phi_\pi(ln\Pi_t-ln\Pi)+\Phi_y(lnY_t-lnY_{t-1})]+s_{b,k}\epsilon_{b,k,t} \tag{22}$$

$$\kappa_{f,t} = (1-\rho_{f,k})k_{f,ss}+\rho_{f,k}k_{f,t-1}-\eta_{f,k}(1-\rho_{f,k})[\Phi_\pi(ln\Pi_t-ln\Pi)+\Phi_y(lnY_t-lnY_{t-1})]+s_{f,k}\epsilon_{f,k,t} \tag{23}$$

6.3.1 Lending programme - QE: Trade-off

Given that the scarcity channel and the liquidity channel have opposite effects on the enforcement constraint of the financial intermediary, the aim of this subsection is to assess their net effect on output stabilisation. We show that the effects of the liquidity channel, generated by endogenising the collateral policy, outweigh the effects of the scarcity channel.

To allow monetary policy to respond endogenously, we simulate an exogenous negative credit shock. Figure 10 below shows the IRFs to a credit shock[34] to which the central bank respond in four different monetary policy scenarios: i) without any UMP (blue-dotted line); ii) only endogenous QE: sovereign bonds purchases as per equation 25 (solid orange line), iii) only endogenous collateral policy: the haircut on sovereign bonds is set as per equation 26 (solid purple line), and iv) endogenous QE and endogenous collateral policy (solid green line).[35] At steady state we impose that the central bank requires sovereign bond as collateral.[36].

[34]To achieve this, the paper follows [Sims and Wu, 2020]: first, it simulates credit shocks of 1.5 standard deviations for 6 periods, pushing the economy to the ZLB; second, it runs the simulation a second time adding a further credit shock of 1 standard deviation in period 7,to which endogenous monetary policy responds; third, it takes the difference between the simulation with the additional credit shock and the simulation without it — the resulting IRFs are presented in Figure 10 below.

[35]QE and collateral policy are calibrated to achieve the same output stabilisation as a policy rate cut with both κ_f and κ_b at steady state equal to zero.

[36]This implies that at steady state there are liquidity injections equal to 10% of the value of the intermediaries' sovereign bond holdings

We find that when the policy rate is constrained by the ZLB and the central bank is unable to use UMP, output contracts by -1.7% (blue-dotted line). When instead monetary policy can respond to the credit shock with sovereign bonds purchases, the central bank's balance sheet increases to 5.4% of steady state output, mitigating the contraction: output falls by -1% (solid orange line). Even if QE is effective at stabilising output, it is not the *most* effective monetary tool because it triggers the contractionary scarcity channel highlighted in subsection 6.2. In other words, the sovereign bond purchases, together with the requirement for intermediaries to hold a fraction of sovereign bonds as collateral, generate a pent-up demand for sovereign bonds that *shrinks* the intermediaries' net worth and *lowers* the liquidity injections from the central bank. This deepens the contraction originally caused by the credit shock. To mitigate this self-induced tightening channel, the central bank expands its asset purchases *more* than it otherwise would if the scarcity channel was not present. In this sense, sovereign bonds purchases *by themselves* are <u>not</u> the most effective monetary tool.

If the central bank decides to react to the credit shock only by easing the collateral policy, output falls less than when it deploys QE (purple solid line, -0.9% vs -1%, respectively). The liquidity injections generated by the lower haircut on sovereign bonds increase the central bank balance sheet by 1.5% of steady state output (vs 5.4% generated by QE). In short, collateral easing is more effective than QE: it delivers more output stabilisation with a smaller monetary policy intervention. The reason for the higher effectiveness is due to the different channels of transmission that are at work at the same time: the collateral policy is *fully* expansionary as it works through the liquidity channel (see section 5.1) while QE is only *partially* expansionary as it creates the contractionary scarcity channel.[37]

The experience of the ECB during the Covid-19 pandemic shows that monetary policymakers respond to a credit shock by engaging in both QE and collateral easing. In our simulation this implies endogenous sovereign bond purchases and endogenous haircut on sovereign bonds (solid green line). It is this unconventional monetary policy combination that achieves the highest degree of output stabilisation: output falls by only -0.78%, almost a quarter less than when the central bank deploys QE. The mix of liquidity injections and asset purchases increases the central bank balance sheet to 5% of steady state output (5.5% with QE). We conclude that also this policy mix is more effective than solely relying on QE. In other words, the liquidity channel generated by the lower haircut is able to offset the scarcity channel generated by the sovereign bonds purchases.

To conclude, even if QE and collateral policy have the same purpose — to act as a backstop during periods of market malfunctioning [BIS, 2022] — these simulations highlight the different channels of transmission through which they work and the range of outcomes they can potentially lead to. From a policy perspective, we offer two recommendations. First, when liquidity injections with

[37] In addition, by construction of the enforcement constraint in equation 4, the effectiveness of liquidity injection is higher than sovereign bonds purchases (as explained in section 5.1).

sovereign bonds as collaterals have already been implemented in previous periods, the most effective framework to respond to a credit crisis is a combination of sovereign bond purchases and lower haircut on sovereign bonds. It is this *combination* that will deliver the highest output stabilisation. Second, our simulations discourage engaging solely in sovereign bonds purchases and instead support, as second best option, a greater reliance on lending provisions. Working through the expansionary liquidity channel, it is the lending provisions that will deliver more output stabilisation with a smaller monetary policy intervention than QE.

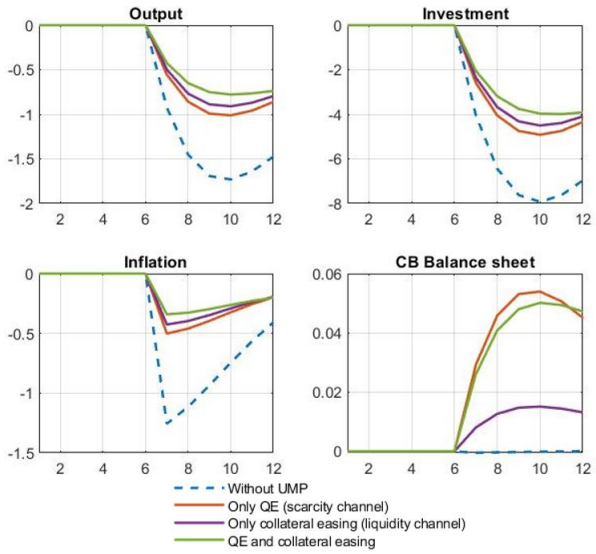


Figure 10: Credit shock with endogenous QE and endogenous collateral policy

6.3.2 Lending programme - QE: Synergy

This subsection focuses on the amplification mechanism that is generated when the central bank purchases sovereign bonds through its QE programme while requiring corporate bonds as collateral for its lending programme. By endogenesing the collateral policy, this subsection shows that we can exploit the portfolio rebalancing channel of QE to enhance the effectiveness the lending programme.

Figure 11 below shows the IRFs to a credit shock[38] in five monetary policy scenarios: i) without any UMP (blue-dotted line); ii) only endogenous QE — sovereign bonds purchases as per equation 25 — without any collateral requirement at steady state (solid orange line), iii) only endogenous QE with corporate

[38]To achieve this, we follow the same methodology implemented for Figure 10: first, we simulate credit shocks of 1.5 standard deviations for 6 periods, pushing the economy to the ZLB; second, we run the simulation a second time adding a further credit shock of 1 standard deviation in period 7, to which endogenous monetary policy responds; third, we take the difference between the simulation with the additional credit shock and the simulation without it — the resulting IRFs are presented in Figure 10 below.

bond required as collateral at steady state[39] (solid purple line), iv) only endogenous collateral policy: the haircut on corporate bonds is set as per equation 27 (solid green line), and v) endogenous QE and endogenous collateral policy (solid light blue line).[40]

Our simulations find that when the policy rate is constrained by the ZLB and the central bank does not engage in either QE or lending programmes, output contracts by -1.7% (blue-dotted line). If the central bank responds to the credit shock with sovereign bonds purchases (without having any required collateral at steady state), the central bank's balance sheet increases to 4.9% of steady state output, mitigating the contraction: output falls by -0.9% (solid orange line). As found in the previous policy experiment, QE alone is effective at stabilising output, but it is not the *most* effective strategy. In fact, if the central bank at steady state requires a fraction of the intermediaries' corporate bonds to be pledged as collateral for the lending facility, then the amplification mechanism described in subsection 6.2 is triggered. The strength of this mechanism depends on the size of the haircut applied at steady state.In other words, by purchasing sovereign bonds, the central bank indirectly increases the price of corporate bonds (through the portfolio rebalancing channel), allowing more liquidity injections. Since the liquidity injections are more effective at stabilising output than sovereign bond purchases — by construction, as explained in section 6.1[41] — the contraction can be mitigated with a less aggressive QE programme. This is the case represented by the purple IRFs: thanks to the collateral requirement at steady state, the central bank is able to achieve the same output stabilisation delivered by QE alone (orange line) but with a smaller balance sheet expansion (4.6% of steady state output vs 4.9%). In this sense, sovereign bonds purchases *by themselves* are not the most effective monetary tool. This is the same conclusion of the previous subsection, but we reach it through a different transmission channel: the portfolio rebalancing channel rather than the scarcity channel.

If the central bank reacts to the credit shock only by easing the collateral policy without engaging in any sovereign bond purchases (green line), its operations work entirely through the liquidity channel. In this case, output falls as much as when the central bank deploys QE but the balance sheet records less than a third of the increase generated by QE. In short, liquidity injections through collateral easing are more effective than sovereign bond purchases, as by construction (section 5.1[42]).

Finally, in the spirit of the ECB strategy during the Covid-19 pandemic, we simulate a credit shock to which the central bank reacts using both QE and collateral easing. In our simulation this implies endogenous sovereign bond purchases and endogenous haircut on corporate bonds (solid light blue line).

[39] This implies that at steady state there are liquidity injections equal to 10% of the value of the intermediaries' corporate bond holdings.

[40] As for the IRFs in Figure 10, QE and collateral policy are calibrated to achieve the same output stabilisation as a policy rate cut with both κ_f and κ_b at steady state equal to zero.

[41] See the enforcement constraint at equation 4.

[42] The lending provisions ease the enforcement constraint more than sovereign bond purchases (see equation 4) because of the calibration of the parameters Δ (0.3) and ζ (1).

This unconventional monetary policy combination achieves the highest degree of output stabilisation — output falls by -0.8% — with a central bank balance sheet increase of 4.1% of steady state output. This is a smaller balance sheet expansion than when the central bank engages only in endogenous QE and at steady state requires corporate bonds as collateral (solid purple line) — in that case output contracts by -0.9%. Endogenising both instruments is more effective than endogenising only QE because it allows liquidity injections (that by construction are more effective than QE) to substitute sovereign bond purchases. So even if the balance sheet increase is *smaller*, output contracts less because the *composition* of central bank's assets is different. In other words, endogenising both instruments allows the central bank to exploit the portfolio rebalancing channel and enhance the effectiveness of the lending programme.

To conclude, as in the previous subsection, simultaneously deploying the two UMP tools — endogenous QE and endogenous collateral policy — leads to better outcomes than the sum of their parts. This non-linearity is achieved by fuelling the portfolio rebalancing channel of QE. From a policy perspective, our simulations suggest that engaging strategically in QE and in collateral policy can make monetary policy more effective, leading to higher output stabilisation with a smaller balance sheet intervention.

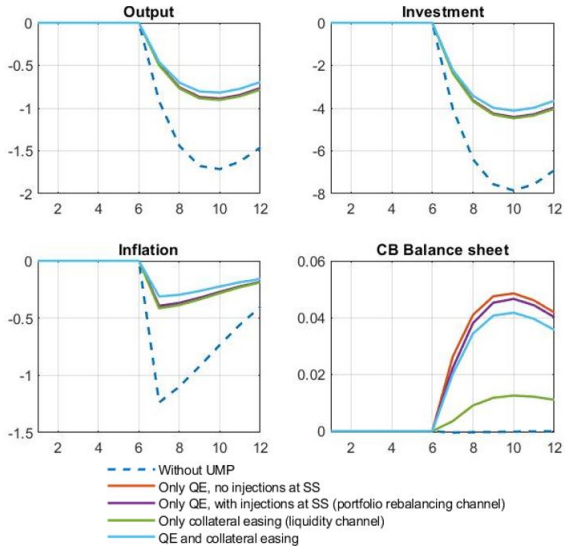


Figure 11: Credit shock with endogenous QE and endogenous collateral policy

6.4 Endogenous NIRP and endogenous lending programmes: The dual rate

In subsection 6.1 we simulated an exogenous shock to the rate applied on the lending programme — what we called "dual rate shock" — while the policy

rate was set at zero. This setting was convenient to study the effectiveness of having the lending facility rate below the Bank rate, nonetheless it did not reflect policymakers' choices. The experience of the ECB shows that dual rate policy is implemented i) in response to a shock, and ii) when the Bank rate is already set negative. To model the ECB decisions we simulate a credit shock to which the central bank reacts by engaging in NIRP and setting the rate on the lending programme *endogenously* below the policy rate. Following the policy rate (equation 14), we endogenize the spread between the lending facility rate R_t^h and the policy rate as per equation 18.

Figure 12 below shows the IRFs to a credit shock in period seven, when the economy is at the ZLB.[43] We explore four different scenarios to study the synergies and state contingencies of the dual rate policy.

The first scenario (blue dotted line) is the baseline: this is an economy that engages in NIRP but *not* in dual rate policy and, at steady state, the loans from the central bank are limited to 10% of the value of the sovereign bonds held by the financial intermediaries. In this setting, investment contracts by -4.7% and the net worth of financial intermediaries shrinks by -4.8%. The capitalisation of the intermediaries decreases because of two reasons: first, the fall in assets value (driven by the credit shock), second, the size of the spread between the policy rate and the deposit rate (driven by NIRP). In other words, as the interest rate on reserves falls by more than 30bps and the deposit rate remains at zero, a "tax" on the intermediaries' net worth arises: this is the contractionary "NIRP banking channel" identified by [Sims and Wu, 2020]. Policymakers are aware of this contractionary channel of monetary policy [Lagarde, 2020], potentially triggering the "reversal rate": the tipping point at which expansionary monetary policy (NIRP) becomes contractionary. The liquidity injections record a small increase: as the interest rate on the lending programme follows the policy rate in negative territory, the loans are offered at a discount, becoming more attractive. The dual rate policy is not activated: the spread between the policy rate and the injection rate is set at zero. Note that, relative to the other scenario, this policy choice leads to the deepest contraction.

The second scenario (orange dotted line) introduces the endogenous dual rate policy. It features a central bank that, as in the baseline model, deploys NIRP and, at steady state, it extends loans for 10% of the value of the sovereign bonds held by financial intermediaries. Differently from the baseline model, however, the central bank engages in endogenous dual rate policy, as per equations 17 and 18. The introduction of the dual rate policy takes the form a 800bps spread between the negative policy rate (-0.30%) and the *more* negative rate on the central bank's loans. Relative to the baseline, the dual rate policy mitigates the contraction — investment falls by -4.2% (vs baseline -4.7%) — and it allows to

[43] To achieve this, we follow the same methodology implemented for the previous policy experiments: first, we simulate credit shocks of 1.5 standard deviations for 6 periods, pushing the economy to the ZLB; second, we run the simulation a second time adding a further credit shock of 1 standard deviation in period 7, to which endogenous NIRP responds; third, we take the difference between the simulation with the additional credit shock and the simulation without it — the resulting IRFs are presented in Figure 12 below.

deploy NIRP less aggressively. There are two reasons for these dynamics: first, the intermediaries' net worth does not fall as much as in the baseline (the NIRP contractionary banking channel is weakened); second, the liquidity injections are larger (the negative rate makes them more attractive). In short, the relatively higher capitalisation and liquidity injections ease the constraint of the financial intermediaries, preventing assets' prices and output to fall as much as in the baseline scenario. In addition, the dual rate policy *prevents* the economy from hitting the contractionary reversal interest rate. We conclude that using dual rate policy while deploying NIRP is preferable than relying solely on NIRP.

The third scenario (purple-dotted line) represents an economy highly reliant on the central bank's liquidity injections. The central bank engages in NIRP and endogenous dual rate policy, as in the second scenario. The only difference with the second scenario is that, at steady state, the central bank extends loans for 50% (not 10%) of the value of the sovereign bonds held by financial intermediaries. The reason for simulating this scenario is to avoid lowering into negative territory the interest rate on the lending provision by 800bps below the policy rate as in the previous experiment, as this policy would be unfeasible. As previously found in section 6.1, the easier the collateral policy, the less aggressive dual rate policy needs to be: the IRFs show that the liquidity injections increase further (14% vs 1.8% in the second scenario), and the spread between the reserve rate and lending programme rate narrows (440bps vs 800 in the second scenario). As the contraction is mitigated (investment falls by -2.6% vs -4.2% in the second scenario), NIRP is deployed less aggressively, supporting financial intermediaries' net worth. Critically, net worth is *accumulated* thanks to the dual rate policy and the smaller haircut, offsetting the contractionary effects coming from the fall in assets' prices and NIRP. Overall, the third scenario shows that the synergies between NIRP and the lending programme are maximised when the central bank responds — in the words of the ECB during the Covid-19 crisis — "forcefully" to the exogenous shock [Schnabel, 2020a].

Finally, the fourth scenario (green dotted line) represents an economy using NIRP, endogenous dual rate *and* endogenous collateral policy. This combination of policy tools was deployed by the ECB in response to the pandemic: NIRP eased financial conditions, the dual rate strategy supported intermediaries' net worth (hit by NIRP) and the collateral policy improved banks' funding conditions and strengthened the transmission of the dual rate strategy (more funding at favourable terms). To be clear, as in the third scenario, the central bank engages in NIRP, endogenous dual rate policy and, at steady state, it extends loans for 50% of the value of the sovereign bonds held by financial intermediaries. In addition, the collateral policy is decided endogenously by the Taylor-type rule of equation 22. The IRFs show that deploying NIRP while *simultaneously* easing the dual rate and collateral policies allows to maintain more room for manoeuvre for the future — the Bank Rate and the rate on the lending facility do not need to be lowered as much into negative territory as in the third scenario — and to deliver a higher degree of output stabilisation.

Overall, this set of policy simulations has shown the strong synergies run-

ning between NIRP and the lending programmes. These positive interactions arise because the dual rate policy mitigates the contraction in banks' net worth induced by NIRP. At the same time, easing the collateral haircut enhances the intermediaries' funding conditions and it strengthens the transmission of the dual rate strategy (more funding at favourable terms). These transmission channels keep the economy away from the reversal interest rate [Lagarde, 2020] and they ensure a higher degree of output stabilisation (compared to deploying these tools in isolation). From a policy perspective, these synergies suggest central banks to "go big and go fast" [Bailey et al., 2020b] when responding to an exogenous shock with NIRP and lending programmes.

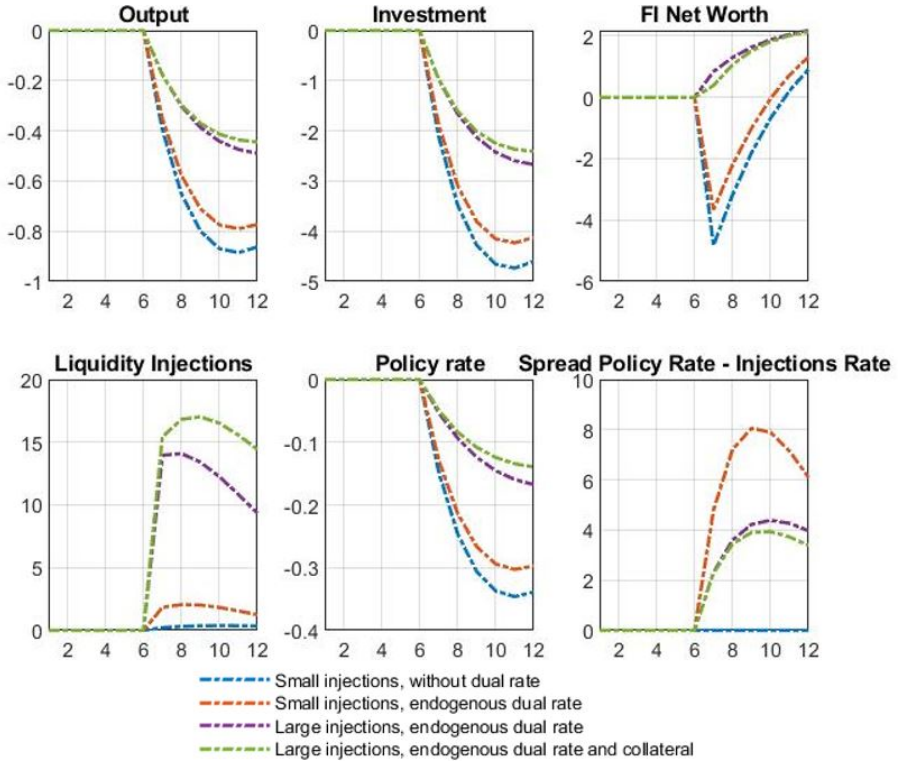


Figure 12: NIRP and endogenous dual rate

6.5 Policy Normalisation: Choosing the Unwinding Pace and Combination of Instruments

Subsection 6.3 found that the most effective framework to respond to a credit crisis is a combination of sovereign bond purchases and lower haircut on sovereign bonds.[44] But how do policymakers eventually exit these two unconventional

[44] When liquidity injections with sovereign bonds as collaterals have already been implemented in previous periods.

programmes and normalise the monetary policy stance to achieve their mandate without causing a taper tantrum?[45] Do different unwinding paces and combinations of tools lead to different recoveries and sizes of central banks' balance sheets? If so, is there a way to do this that minimises potential detrimental effects? In short, what does a feasible and useful exit strategy look like? These are the types of questions we aim to answer in this sub-section.

There is a lack of empirical literature on the unwinding of UMP tools. This is mostly due to the scarce engagement of central banks with UMP tightening: before the current normalisation phase, QT has been attempted only by BoJ in 2006 and the Fed in 2017 [BIS, 2019]. Equally thin is the theoretical literature, that focuses mostly on the process of reversing QE — known as Quantitative Tightening (QT, see [Sims and Wu, 2020] and [Karadi and Nakov, 2021]). However, these theoretical studies do not capture the interactions with the unwinding of the other UMP tools, hence they do not provide a realistic representation of the normalisation process. Several central banks' documents [BoE, 2021] and some qualitative academic analyses [Forbes, 2021] attempt to overcome this limitation, studying in unison QT and policy rate hikes. This evidence is helpful to inform the sequencing of QT and Bank rate, but its ability to fully represent the normalisation process is hamstrung by the absence of the lending programmes.

Lacking extensive research and policy experience, central banks have adopted gradualism and predictability as their mantra to unwind UMP.[46] Despite the finely balanced tightening strategy — described by BoE Chief Economist [Pill, 2021] as "crossing the river by feeling the stones" — the policy normalisation process remains "extraordinarily complex"[Panetta, 2022a]. The risks to monetary and financial stability arise from the *pace* and *amount* of tightening as well as the *mix* of policy instruments. A "normalisation tantrum" can in fact be triggered if the unconventional stimulus is unwound:

- Too quickly, triggering a repricing of market expectations, similar to the 2013 US taper tantrum;
- Too extensively, exacerbating any liquidity gap in the market, as in the US Money Markets in September 2019; or
- Through a tool to which the economy is highly dependent. For instance, the ECB in 2019 did not let its TLTRO programme expire to avoid "cliff effects" — a concentration of payments and maturities at the end of the programme creating stress in funding markets — and instead it announced a new package of funds (TLTRO III).

[45] Following an announcement in May 2013 by former Federal Reserve Chair Ben Bernanke that the Fed would start reducing its asset purchases "in the next few [FOMC] meetings" [USCongress, 2013], the bond market reacted sharply, as investors sold off bonds. The 10-year US Treasuries' yield rose from 2% in May 2013 to around 3% in December, causing higher mortgages rates in the US and balance of payment stress in emerging markets [Davies, 2021].

[46] The importance of a gradual unwinding of UMP was highlighted already in 2017 by the Fed [Ennis and Kirk, 2022] and more recently echoed by the BoE [Bailey et al., 2020a], ECB [Panetta, 2022a] and BIS [BIS, 2019].

Our policy experiments and related simulations below focus on two of these risks: the pace of tightening and the mix of instruments.

The aim of the simulation is to study the effects on output and central bank's balance sheet of different tightening paces and combinations of QE/lending programmes. Following [Sims and Wu, 2020], Figure 13 below shows the IRFs to credit shocks in periods 1-7 with endogenous QE and endogenous collateral policy (lending programme) as in equations 22 and 23, respectively. In other words, the central bank reacts to the exogenous shock by engaging in sovereign bond purchases and by lowering the haircut on sovereign bonds, as in subsection 5.3. Both the expansionary liquidity channel and the contractionary scarcity channel arise.[47]. We generate four scenarios of policy normalisation once the ZLB stops binding: first, the solid orange line represents a central bank that unwinds simultaneously QE and the lending programme in a smooth manner — this replicates the gradual and predictable normalisation process envisaged by central banks.[48]

In this setting (purple line), the autoregressive parameter ρ_f is equal to 0.8: this can be thought as "smooth QT". The yellow dotted line represents the IRFs when the central bank adopts QE but it unwinds the balance sheet through an immediate QT process — ρ_f is equal to 0. Finally, the green dotted line represents the IRFs when the central bank adopts QE however it does not implement QT, it carries forward a large balance sheet without unwinding it — ρ_f is equal to 1.

Second, the green dotted line represents the opposite policy choice: the central bank never fully unwinds its lending programmes nor QE, reinvesting continuously the principal payments from maturing bonds.[49] This is the strategy adopted by the ECB before the Covid-19 pandemic. As the side effects of UMP have increased over time [Schnabel, 2022], the ECB as well as other major central banks have taken steps to unwind their balance sheet policies. However, in practice, it may be unfeasible to unwind completely[50] and within the same time frame[51] both policies (QE and the lending programmes), so the next two scenarios present a staggered normalisation strategy. The purple dotted line represents a central bank that ends immediately the lending programmes but

[47]At steady state we impose that the central bank requires sovereign bond as collateral. This implies that at steady state there are liquidity injections equal to 10% of the value of the intermediaries' sovereign bond holdings

[48]To model this policy strategy, the autoregressive central bank bond holding parameter ρ_b and autoregressive sovereign bond collateral parameter $\rho_{b,k}$ are equal to 0.8 (see [Sims and Wu, 2020])— this can be thought as "smooth QT" and smooth exit from the lending programme.

[49]To model a central bank that carries forward a large balance sheet without unwinding its policies, we set both autoregressive parameters ρ_b e $\rho_{b,k}$ equal to 1.

[50]Both ECB [Panetta, 2022a] and BoE[Bailey et al., 2020a] agree that going forward the steady state size of their balance sheets will be larger than before the Global Financial Crisis. For the reasons, see [Hauser, 2021a]

[51]BoE, for instance, stopped asset purchases in December 2021 and as of June 2022 it has not started the sales of UK government bonds yet, while the deadline for the drawdown period of its lending programme (the Term Funding Scheme with additional incentives for SMEs, (TFSME) was set at October 2021.

it does not unwind QE.[52] The yellow dotted line, instead, represents the opposite case: the lending programme is never completely unwound but the QE programme is exited quickly.[53]

The most effective normalisation strategy is the smooth unwinding of both QE and the lending programme (orange line). In this case, the central bank balance sheet increases the least (27% of steady state output) while achieving the highest output stabilisation (output contracts by -6.7%). However, an inter-temporal trade-off arises as the recovery is slower than in the other three scenarios. The reason for the worst performance during the recovery is due to agents' expectations — the gradual normalisation keeps interest rates low for longer, so agents procrastinate investment decisions, slowing the recovery [Sims and Wu, 2020] — and financial intermediaries' net worth — the gradual unwinding keeps interest rate spreads compressed, hurting net interest margins and consequently intermediation [Karadi and Nakov, 2021].

Since policy experience shows that the simultaneous, gradual unwinding of both QE and the lending programme is not feasible, we analyse the second best exit strategy: a quick unwinding of QE without a full normalisation of the lending programmes (yellow line). In this case the central bank balance sheet increases more than in the previous scenario (31% of steady state output vs 27%) while delivering almost the same output stabilisation during the recession. In the recovery phase, when the ZLB stops binding, output grows faster. The intuition for these results is the following: the missing normalisation of the lending programme *once the ZLB stops binding* suggests agents spread their investment decisions over time, deepening the crisis *when the ZLB is binding* and requiring a more aggressive monetary policy stance — hence the larger central bank balance sheet. During the recovery, when the ZLB is lifted, the central bank quickly sells sovereign bonds previously purchased through QE: these sales erase the contractionary scarcity effect but they also tighten financial conditions. In period 15, as seen in the output panel of Figure 13, the recovery is stalled but the wider interest rate spreads re-build financial intermediaries'net worth faster, supporting asset prices and, consequently, output — hence the better performance during the recovery.

Should the central bank decide to implement the opposite staggered strategy — to end the lending programme quickly but to continue rolling over its sovereign bond purchases over time (purple dotted line) — its balance sheet would increase more (33% of steady state output) and remain *four times larger* than the previous case once the ZLB is lifted. Output would contract more (-7.2%) during the recession, but grow as fast during the recovery.

Despite the good performance during the recovery, this strategy is highly inefficient, for two reasons: first, the scarcity effect generated by the central bank's pent up demand for sovereign bonds persists also after the ZLB is lifted

[52] This strategy is modelled by setting the QE autoregressive parameter equal to 1 and the lending programme autoregressive parameter equal to 0.

[53] Opposite to the previous case, this strategy is modelled by setting the QE autoregressive parameter equal to 0 and the lending programme autoregressive parameter equal to 1.

(as QE is never unwound), making large sovereign bonds purchases necessary only to deliver the same output path of the previous strategy. Second, the economy reverts back to steady state with an endogenous scarcity effect that is now stronger than before the central bank's intervention: this implies that even larger sovereign bonds purchases will be needed in the next recession. Echoing [Borio, 2020], we can also show that the prolonged use of UMP tools exhibits diminishing returns and it might narrow the room for policy manoeuvre in the future. In short, large, permanent central bank balance sheets are not inconsequential as previously thought: they significantly affect the performance of the economy during the crisis [Sims and Wu, 2020] as well as in future crises. This is an important finding from our policy exercises.

Finally, we analyse the case in which the central bank does not unwind either QE or the lending programme (green dotted line). This is the least effective strategy, as output contracts the most while the central bank balance sheet becomes — and remains — the largest. Two main channels lead to these outcomes: persistent asset scarcity after the ZLB is lifted and agents' expectations of a low for longer environment. The missing normalisation of both UMP tools makes these expectations stronger than in the other simulations, deepening the recession. The severe contraction, however, widens interest rate spreads that quickly rebuild financial intermediaries' net worth, fuelling the fastest recovery amongst our set of policy exercises. Despite the good performance during the recovery, this strategy has long lasting negative consequences: it leaves the economy highly dependent on central bank's interventions — with adverse repercussions on the market ecosystem [BIS, 2019] — and it endogenises a strong scarcity effect — narrowing the room for policy manoeuvre in the future.

To conclude, the knowledge on the exit from UMP is limited, leaving "policymakers uncertain about the effects of their policy on the economy"[Panetta, 2022b]. This section informs the policy debate by showing that the pace of unwinding and the combination of tools that are unwound have significant effects on the performance of the economy during the recession, the recovery and future crises. Our simulations indicate that the most effective strategy is a smooth and complete unwinding of both QE and the lending programme. If this was not possible, QE should be exited quickly and the lending programme carried forward. Compared to never fully unwinding the unconventional stimulus, this strategy leaves the economy less dependent on central bank's interventions and, going forward, more reactive to them, ensuring the effectiveness of future monetary policy decisions.

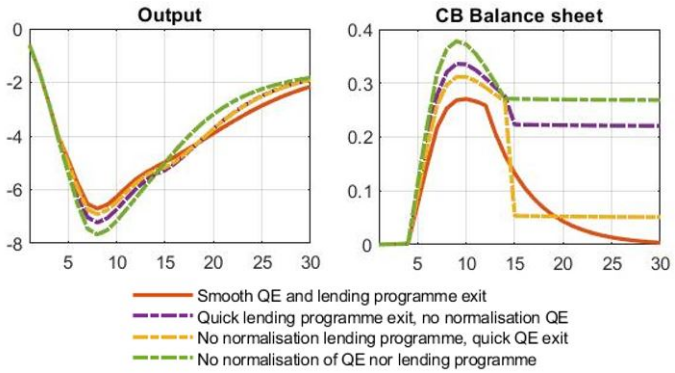


Figure 13: Unwinding QE and lending programmes: different paces of normalisation and combinations of instruments

Table 2: Different unwinding paces and combinations of tools

Unwinding pace and tools' combination		**Output**	**CB Balance Sheet**
Smooth QE and lending programme exit	Crisis:*	-6.7%	26.8%
	Recovery:**	-2.9%	1.3%
No normalisation lending programme, quick QE exit	Crisis:	-6.9%	31.1%
	Recovery:	-2.5%	5.1%
Quick lending programme exit, no normalisation QE	Crisis:	-7.2%	33.6%
	Recovery:	-2.5%	22.1%
No normalisation of QE nor lending programme	Crisis:	-7.7%	37.8%
	Recovery:	-2.2%	26.9%

Notes: *Measured in period 8, at the trough of the cycle.**Measured in period 25. Output is expressed in percentage deviations from the steady state; the central bank's balance sheet is expressed in percentage of steady state output.

7 Conclusions

In this paper we have developed a theoretical DSGE model to study the synergies and trade-offs between the lending programmes and three UMP instruments: QE, NIRP and FG. We found that, when the lending programmes are deployed in isolation, they are more effective than sovereign bonds purchases in supporting aggregate demand. When,instead, the lending programmes are deployed simultaneously with the other UMP instruments, the synergies that arise from the interactions make *three cases for their concerted deployment*. First, when the lending programmes are deployed simultaneously with QE, synergies — working through the collateral value — and trade-offs — generated by the scarcity of available assets — arise. By setting its collateral policy, the cen-

tral bank can strengthen the positive interactions and overcome the trade-offs, improving monetary policy effectiveness. Second, when the lending programmes are deployed simultaneously with NIRP, the dual rate system supports financial intermediaries' net worth. This synergy prevents the economy from hitting the reversal interest rate, again increasing monetary policy effectiveness. Finally, once the economy is in recovery, the simultaneous, smooth and complete unwinding of both QE and the lending programme ensures the most effective normalisation policy. The next step in our research will be to extend the model by letting the central bank lend directly to corporates. This will allow to compare the transmission mechanisms and effectiveness of the Wall Street vs Main Street Lending Programmes.

8 Annex 1: Exogenous UMP shocks

Following Figure 7, we compare the IRFs to eight different monetary policy shocks once the economy is at the ZLB. The eight monetary policy shocks are: three shocks to the lending programme — representing sovereign bond collateral easing (light blue dotted line), corporate bond collateral easing (red dotted line) and dual rate policy easing (dark blue dotted line) — a policy rate shock (solid blue line), a corporate bond QE shock (orange dotted line), a sovereign bond QE shock (yellow dotted line), a NIRP shock (green dotted dotted line) and finally a FG shock (purple dotted line). The shocks are calibrated to match the same increase in output given by the policy rate cut shock (0.49% in period nine).

8.1 30% haircut on sovereign bond

The calibration used for Figure 14 below differs from the calibration used in the paper for Figure 7 as the parameter $\kappa_{b,t}$, governing the haircut on sovereign bond, is set at 30% (vs 10% in the paper). This implies that there are more lending provisions in this Annex's simulation than in the paper's. The larger liquidity injections ease the financial conditions, as such the dual rate strategy does not need to be applied as aggressively: the interest rate on the lending facility is set 200bps below the policy rate (vs more than 600bps in the paper's simulation).

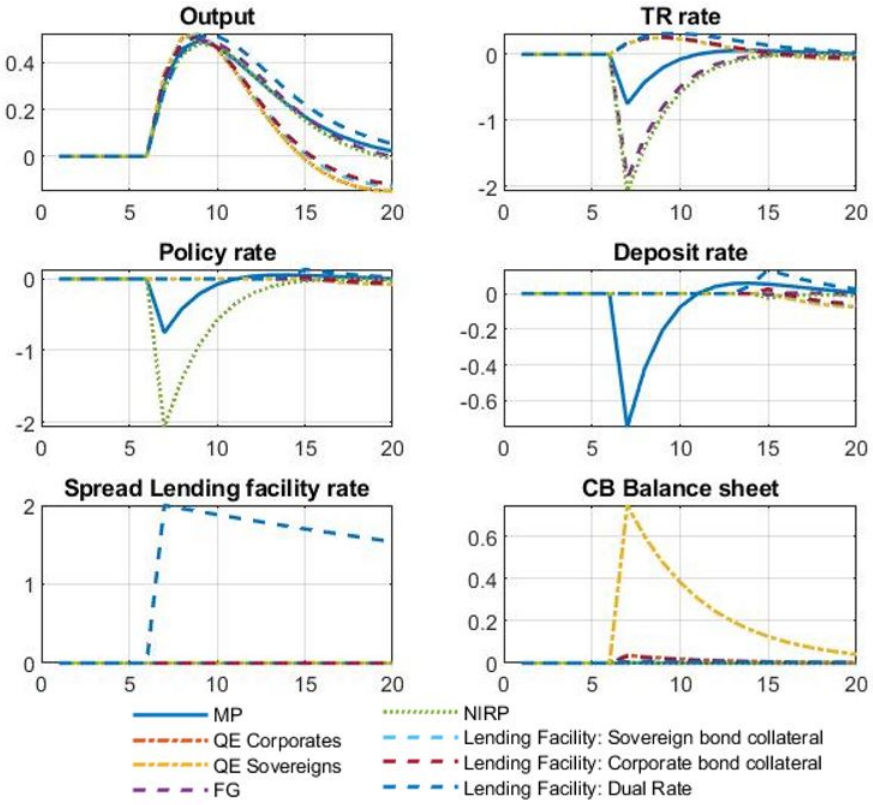


Figure 14: Monetary Policy Shocks

8.2 50% haircut on sovereign bond

Following up on the previous policy experiment, this subsection calibrates the parameter $\kappa_{b,t}$ at 50% — five times larger than the paper's calibration. The higher liquidity injections make a large cut to the interest rate on the lending facility unnecessary: in Figure 15 below the interest rate on the lending facility is set 100bps below the policy rate (vs more than 600bps in the paper's simulation).

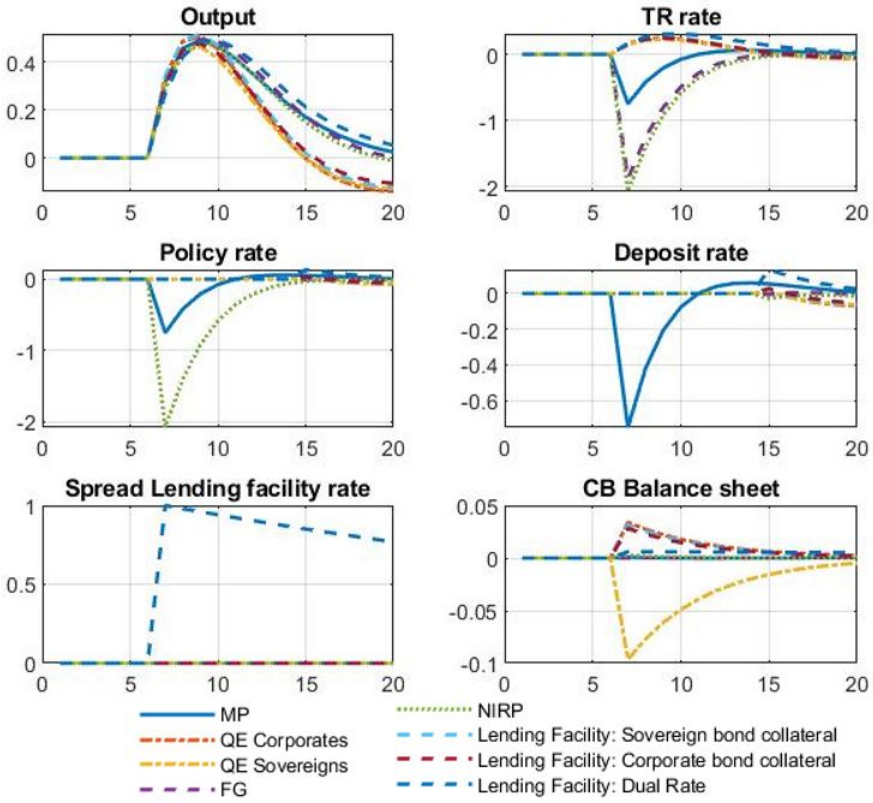


Figure 15: Monetary Policy Shocks

References

[Albertazzi et al., 2021] Albertazzi, U., Becker, B., and Boucinha, M. (2021). Portfolio rebalancing and the transmission of large-scale asset purchase programs: Evidence from the Euro area. *Journal of Financial Intermediation*, 48(C).

[Altavilla et al., 2021] Altavilla, C., Lemke, W., Linzert, T., Tapking, J., and von Landesberger, J. (2021). Assessing the efficacy, efficiency and potential side effects of the ECB's monetary policy instruments since 2014. Occasional Paper Series 278, European Central Bank.

[Bagehot, 1873] Bagehot, W. (1873). *Lombard Street: A Description of the Money Market*. Number bagehot1873 in History of Economic Thought Books. McMaster University Archive for the History of Economic Thought.

[Bailey et al., 2020a] Bailey, A., Bridges, J., Harrison, R., Jones, J., and Mankodi, A. (2020a). The central bank balance sheet as a policy tool: past, present and future. Bank of England working papers 899, Bank of England.

[Bailey et al., 2020b] Bailey, A., Bridges, J., Harrison, R., Jones, J., and Mankodi, A. (2020b). The central bank balance sheet as a policy tool: past, present and future. Bank of England working papers 899, Bank of England.

[Barbiero et al., 2021] Barbiero, F., Boucinha, M., and Burlon, M. (2021). Tltro iii and bank lending conditions. ECB Economic Bulletin 6, European Central Bank.

[Barbiero et al., 2022] Barbiero, F., Burlon, L., Dimou, M., and Toczynski, J. (2022). Targeted monetary policy, dual rates and bank risk taking. Working Paper Series 2682, European Central Bank.

[Bindseil et al., 2017] Bindseil, U., Corsi, M., Sahel, B., and Visser, A. (2017). The Eurosystem collateral framework explained. Occasional Paper Series 189, European Central Bank.

[BIS, 2015] BIS (2015). *Central bank operating frameworks and collateral markets*. Number 53 in CGFS Papers. Bank for International Settlements.

[BIS, 2019] BIS (2019). Large central bank balance sheets and market functioning. Markets Committee Papers 11, Bank for International Settlements.

[BIS, 2022] BIS (2022). Market dysfunction and central bank tools: Insights from a markets committee working group chaired by andrew hauser (bank of england) and lorie logan (federal reserve bank of new york). Technical report, Bank for International Settlements.

[BoE, 2021] BoE (2021). Monetary policy report. Technical report.

[Borio, 2020] Borio, C. (2020). When the unconventional becomes conventional. Technical Report Speech at at The ECB and Its Watchers XXI, Bank of International Settlements.

[Brunnermeier and Koby, 2018] Brunnermeier, M. K. and Koby, Y. (2018). The Reversal Interest Rate. NBER Working Papers 25406, National Bureau of Economic Research, Inc.

[Busetto et al., 2022] Busetto, F., Chavaz, M., Froemel, M., Joyce, M., Kaminska, I., and Worlidge, J. (2022). Qe at the bank of england: a perspective on its functioning and effectiveness (quarterly bulletin 2022 q1). Technical report, Bank of England.

[Cahn et al., 2017] Cahn, C., Matheron, J., and Sahuc, J. (2017). Assessing the Macroeconomic Effects of LTROs during the Great Recession. *Journal of Money, Credit and Banking*, 49(7):1443–1482.

[Carpinelli and Crosignani, 2021] Carpinelli, L. and Crosignani, M. (2021). The design and transmission of central bank liquidity provisions. *Journal of Financial Economics*, 141(1):27–47.

[Cavallino and Fiore, 2020] Cavallino, P. and Fiore, F. D. (2020). Central banks' response to Covid-19 in advanced economies. BIS Bulletins 21, Bank for International Settlements.

[Chen et al., 2020] Chen, Q., Goldstein, I., Huang, Z., and Vashishtha, R. (2020). Liquidity Transformation and Fragility in the US Banking Sector. NBER Working Papers 27815, National Bureau of Economic Research, Inc.

[Churm et al., 2021] Churm, R., Joyce, M., Kapetanios, G., and Theodoridis, K. (2021). Unconventional monetary policies and the macroeconomy: The impact of the UK's QE2 and funding for lending scheme. *The Quarterly Review of Economics and Finance*, 80(C):721–736.

[Corradin et al., 2017] Corradin, S., Heider, F., and Hoerova, M. (2017). On collateral: implications for financial stability and monetary policy. Working Paper Series 2107, European Central Bank.

[Crosignani et al., 2020] Crosignani, M., Faria-e Castro, M., and Fonseca, L. (2020). The (Unintended?) consequences of the largest liquidity injection ever. *Journal of Monetary Economics*, 112(C):97–112.

[Darracq Pariès et al., 2020] Darracq Pariès, M., Kok, C., and Rottner, M. (2020). Reversal interest rate and macroprudential policy. Working Paper Series 2487, European Central Bank.

[Davies, 2021] Davies, S. (2021). Don't look to the 2013 tantrum for the effect of tapering on emerging markets. Technical report, Federal Reserve Bank of Dallas.

[de Groot and Haas, 2022] de Groot, O. and Haas, A. (2022). The Signalling Channel of Negative Interest Rates. Technical report.

[Diamond and Dybvig, 1983] Diamond, D. W. and Dybvig, P. H. (1983). Bank Runs, Deposit Insurance, and Liquidity. *Journal of Political Economy*, 91(3):401–419.

[D'Amico and Kaminska, 2019] D'Amico, S. and Kaminska, I. (2019). Credit easing versus quantitative easing: evidence from corporate and government bond purchase programs. Bank of England working papers 825, Bank of England.

[Eberly et al., 2020] Eberly, J. C., Stock, J. H., and Wright, J. H. (2020). The Federal Reserve's Current Framework for Monetary Policy: A Review and Assessment. *International Journal of Central Banking*, 16(1):5–71.

[ECB, a] ECB. *Economic Bulletin*, 7.

[ECB, b] ECB. Technical report, European Central Bank.

[ECB, 2020a] ECB (2020a). Press release: Ecb announces package of temporary collateral easing measures. Technical report.

[ECB, 2020b] ECB (2020b). Press release: Ecb takes steps to mitigate impact of possible rating downgrades on collateral availability. Technical report.

[Eggertsson et al., 2019] Eggertsson, G. B., Juelsrud, R. E., Summers, L. H., and Wold, E. G. (2019). Negative Nominal Interest Rates and the Bank Lending Channel. NBER Working Papers 25416, National Bureau of Economic Research, Inc.

[Ennis and Kirk, 2022] Ennis, H. M. and Kirk, K. (2022). Projecting the Evolution of the Fed's Balance Sheet. *Richmond Fed Economic Brief*, 22(15).

[Forbes, 2021] Forbes, K. (2021). Unwinding monetary stimulus in an uneven economy: Time for a new playbook? paper prepared for federal reserve bank of kansas city's jackson hole symposium on macroeconomic policy in an uneven recovery. Technical report.

[Furkan Abbasglu et al., 2019] Furkan Abbasglu, O., Kanik, B., and Mimir, Y. (2019). Central Bank Collateral Framework as an Unconventional Policy Tool. *Working Paper*.

[García-Posada and Marchetti, 2016] García-Posada, M. and Marchetti, M. (2016). The bank lending channel of unconventional monetary policy: The impact of the VLTROs on credit supply in Spain. *Economic Modelling*, 58(C):427–441.

[Gertler and Karadi, 2013] Gertler, M. and Karadi, P. (2013). QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool. *International Journal of Central Banking*, 9(1):5–53.

[Gertler and Kiyotaki, 2010] Gertler, M. and Kiyotaki, N. (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. In Friedman, B. M. and Woodford, M., editors, *Handbook of Monetary Economics*, volume 3 of *Handbook of Monetary Economics*, chapter 11, pages 547–599. Elsevier.

[Gocheva et al., 2022] Gocheva, V., Mudde, Y., and Tapking, J. (2022). Liquidity coverage ratios and monetary policy credit in the time of Corona. Working Paper Series 2668, European Central Bank.

[Grandia et al., 2019] Grandia, R., Hänling, P., Russo, M. L., and Aberg, P. (2019). Availability of high-quality liquid assets and monetary policy operations: an analysis for the euro area. Occasional Paper Series 218, European Central Bank.

[Guerrieri and Iacoviello, 2015] Guerrieri, L. and Iacoviello, M. (2015). OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70(C):22–38.

[Hauser, 2021a] Hauser, A. (2021a). Bigger, broader, faster, stronger? how much should tomorrow's central bank balance sheets do, and what should we leave to financial markets? some principles for good parenting. Technical Report Speech at the International Finance and Banking Society (IFABS) 2021 Oxford Conference on The Financial System(s) of Tomorrow, Said Business School, University of Oxford, Bank of England.

[Hauser, 2021b] Hauser, A. (2021b). From lender of last resort to market maker of last resort via the dash for cash: why central banks need new tools for dealing with market dysfunction. Technical Report Speech given at Reuters, London, Bank of England.

[Hutchinson and Mee, 2020] Hutchinson, J. and Mee, S. (2020). The impact of the ECB's monetary policy measures taken in response to the COVID-19 crisis. *Economic Bulletin Boxes*, 5.

[Iacoviello, 2005] Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. *American Economic Review*, 95(3):739–764.

[Karadi and Nakov, 2021] Karadi, P. and Nakov, A. (2021). Effectiveness and addictiveness of quantitative easing. *Journal of Monetary Economics*, 117(C):1096–1117.

[Kiyotaki and Moore, 1997] Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248.

[Kuttner, 2018] Kuttner, K. N. (2018). Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond. *Journal of Economic Perspectives*, 32(4):121–146.

[Lagarde, 2020] Lagarde, C. (2020). The monetary policy strategy review: some preliminary considerations. Technical Report Speech at 'The ECB and Its Watchers XXI', European Central Bank.

[Lane, 2020a] Lane, P. (2020a). The monetary policy package: An analytical framework. Technical report, European Central Bank.

[Lane, 2019] Lane, P. R. (2019). Monetary policy and below-target inflation. Technical Report Speech at the Bank of Finland conference on Monetary Policy and Future of EMU, European Central Bank.

[Lane, 2020b] Lane, P. R. (2020b). The monetary policy toolbox: evidence from the euro area. Technical Report Speech at the 2020 US Monetary Policy Forum, European Central Bank.

[Legroux et al., 2018] Legroux, V., Rahmouni-Rousseau, I., Szczerbowicz, U., and Valla, N. (2018). Stabilising virtues of central banks: (re)matching bank liquidity. Technical report.

[Panetta, 2022a] Panetta, F. (2022a). Normalising monetary policy in non-normal times. Technical Report Lecture hosted by the SAFE Policy Center at Goethe University and the Centre for Economic Policy Research (CEPR), European Central Bank.

[Panetta, 2022b] Panetta, F. (2022b). Small steps in a dark room: guiding policy on the path out of the pandemic. Technical Report Online seminar organised by the Robert Schuman Centre for Advanced Studies and Florence School of Banking and Finance at the European University Institute, European Central Bank.

[Pill, 2021] Pill, H. (2021). Uk monetary policy: Crossing the river by feeling the stones. Technical Report Speech at the Confederation of British Industry (CBI), Bank of England.

[Quint and Tristani, 2018] Quint, D. and Tristani, O. (2018). Liquidity provision as a monetary policy tool: The ecb's non standard measures after the financial crisis. *Journal of International Money and Finance*, 80:15–34.

[Rostagno et al., 2019a] Rostagno, M., Altavilla, C., Carboni, G., Lemke, W., Motto, R., Saint Guilhem, A., and Yiangou, J. (2019a). A tale of two decades: the ECB's monetary policy at 20. Working Paper Series 2346, European Central Bank.

[Rostagno et al., 2019b] Rostagno, M., Altavilla, C., Carboni, G., Lemke, W., Motto, R., Saint Guilhem, A., and Yiangou, J. (2019b). A tale of two decades: the ECB's monetary policy at 20. Working Paper Series 2346, European Central Bank.

[Saunders, 2020] Saunders, M. (2020). Some monetary policy options – if more support is needed. Technical Report Online Speech, Bank of England.

[Schabert, 2015] Schabert, A. (2015). Optimal central bank lending. *Journal of Economic Theory*, 157(C):485–516.

[Schnabel, 2020a] Schnabel, I. (2020a). The ecb's response to the covid-19 pandemic. Technical Report Speech at the 24-Hour Global Webinar co-organised by the SAFE Policy Center on The COVID-19 Crisis and Its Aftermath: Corporate Governance Implications and Policy Challenges, European Central Bank.

[Schnabel, 2020b] Schnabel, I. (2020b). Going negative: the ecb's experience. Technical Report Speech Roundtable on Monetary Policy, Low Interest Rates and Risk Taking at the 35th Congress of the European Economic Association, European Central Bank.

[Schnabel, 2022] Schnabel, I. (2022). Finding the right sequence. Technical Report Speech at a virtual policy panel on Unwinding QE at the first annual Bank of England Agenda for Research (BEAR) conference, European Central Bank.

[Sims and Wu, 2020] Sims, E. and Wu, J. C. (2020). Evaluating central banks' tool kit: Past, present, and future. *Journal of Monetary Economics*.

[Ulate, 2021] Ulate, M. (2021). Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates. *American Economic Review*, 111(1):1–40.

[USCongress, 2013] USCongress (2013). The economic outlook, hearing before the joint economic committee, congress of the united states, one hundred thirteenth congress, first session. Technical report, Joint Economic Committee, US Congress.

[Wu and Xia, 2018] Wu, J. C. and Xia, F. D. (2018). Negative Interest Rate Policy and the Yield Curve. NBER Working Papers 25180, National Bureau of Economic Research, Inc.