A balance sheet analysis of monetary policy effects on banks

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Abstract: Monetary policy operations affect bank balance sheets (BBSs). This study develops a balance sheet model to examine the impacts of monetary policy operations on banks' ability to supply funds. That ability is assessed using the balance sheet capacities provided by regulatory risk management instruments. The balance sheet approach views a monetary policy operation as a transaction between the central bank and a commercial bank, modeling the transaction as multiple changes to the BBS. This study identifies and distinguishes the effects of multiple changes in the BBS on balance sheet capacity. A balance sheet change resulting from a monetary policy operation may positively or negatively affect balance sheet capacity. Thus, a monetary policy may have a positive and a negative effect simultaneously. Positive (negative) effects result from balance sheet changes that reduce (increase) bank risks, as measured by regulations. As regulatory stringency decreases, the positive effects increase, whereas

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the negative effects remain unchanged. A BBS capacity channel of monetary policy is also shown.

Keywords: Balance sheet; Banking; Monetary policy; Monetary transmission; Regulation

JEL Classification: E51; E52; E58; G21; G28

1. Introduction

The consensus is that the role of banks in transmitting monetary policy is key to understanding monetary policy effects (Adrian & Shin, 2010a; Bernanke, 2023; Boivin et al., 2010; Peek & Rosengren, 2015). In particular, the size or growth rate of bank balance sheets (BBSs) has a significant impact on the financial system and the macroeconomy, especially financial stability (Adrian & Shin, 2010a, 2010b, 2011, 2014; Greenwood et al., 2022; Schularick & Taylor, 2012). Accordingly, monetary policy is weighted toward BBSs (Borio & Disyatat, 2010; Cap et al., 2020). In analyzing the effects of monetary policy on BBSs, a fundamental concern is the impact of monetary policy on balance sheet capacity (Adrian & Shin, 2009, 2010a). Moreover, the influence of monetary policy operations on BBSs leads to an independent transmission mechanism for monetary policy, as Borio and Disyatat (2010) and Disyatat (2008) imply.

The main contributions of this article are summarized as follows. The study uses a balance sheet approach (BSA) to address the issue at hand. The balance sheet analysis complements traditional examinations of monetary policy, which oversimplify monetary policy as a shock to interest rates and downplay the impact of monetary policy on BBSs. The BSA replicates the practical implementation of monetary policy operations by providing their accounting descriptions. Thus, this balance sheet model captures changes in BBSs resulting from monetary policy operations. It then identifies how each change in the BBS affects BBS capacity, or a bank's ability to supply credit. A balance sheet change resulting from a monetary policy operation can be positive or negative depending on how the balance sheet change affects a bank's solvency or liquidity. The (aggregate) effect of a monetary policy operation is calculated by adding the effects of all balance sheet changes it causes. Indeed, the BSA allows the consideration of transactions between the central bank and commercial banks resulting from a monetary policy operation, which constitute the *first-round* impacts of the policy on banks. In this regard, traditional monetary policies, such as open market operations (OMOs), turn out to be less effective in affecting credit supply. More surprisingly, central bank repurchase agreements (repos) and lending may have negative effects. In contrast, central bank interest payments on reserves and purchases of risky securities are much more powerful.

Two building blocks make up the model. First, the BSA is used to determine balance sheet capacity. According to the BSA, the supply of credit is described by BBS expansion, and the limit of balance sheet expansion is the balance sheet capacity.[1] The balance sheet size depends on the ability to take risk (Adrian et al., 2019; Borio & Zhu, 2012; Bruno & Shin, 2015). Bank risks are measured using risk management tools (Adrian & Shin, 2010a, 2014; Li, 2022). In particular, bank regulations as risk management instruments have a threshold effect on banks (Borio & Zhu, 2012). Therefore, a bank regulation implies a limit of a risk taken by banks, or a risk-taking capacity, and thus a balance sheet capacity.[2] The present study shows the risk-taking capacities and corresponding balance sheet capacities associated with Basel III's capital adequacy ratio (CAR), leverage ratio (LR), liquidity coverage ratio (LCR), and net stable funding ratio (NSFR). Moreover, the balance sheet model can establish a

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[1] Some early papers did not use the balance sheet approach (BSA) but mentioned a concept of bank lending capacity comparable to the balance sheet capacity (Bolton & Freixas, 2006; Cecchetti & Li, 2008; Repullo & Suarez, 2000).

[2] The literature on bank regulation effects has suggested that bank regulations limit credit supply (Balasubramanyan & VanHoose, 2013; De Nicolo et al., 2014; Fraisse et al., 2020; Francis & Osborne, 2009; Gropp et al., 2019; King, 2013; Kopecky & VanHoose, 2004b; Li, 2022; Van den Heuvel, 2002, 2007).

connection between bank reserves or capital and balance sheet capacity (Adrian et al., 2019; Adrian & Shin, 2010a, 2014; Li, 2022; Li et al., 2017; Xing et al., 2020; Xiong et al., 2020). The connection between reserves or capital and regulatory-determined balance sheet capacity can be established by a multiplier relationship that varies depending on the specific regulation and bank status (Fraisse et al., 2020; Francis & Osborne, 2009; Gambacorta & Shin, 2018; Juelsrud & Wold, 2020; Kopecky & VanHoose, 2004b; Li, 2022; Li et al., 2017; Xing et al., 2020; Xiong et al., 2020).

The second component is the accounting description of monetary policy based on the balance sheet. The BSA replicates monetary policy operations as they actually occur. Conversely, nearly all examinations of the effects of monetary policy simplify the monetary policy operation as a shock to a single variable, such as bank reserves (Bernanke & Blinder, 1988), bank deposits (Kashyap & Stein, 1995), money growth rates (Bruno & Shin, 2015), or short-term interest rates, including interbank, risk-free, or deposit rates (Adrian et al., 2019; Bernanke & Blinder, 1992; Borio & Gambacorta, 2017; Bruno & Shin, 2015; Disyatat, 2011; Drechsler et al., 2017; Kashyap & Stein, 1995; Kopecky & VanHoose, 2004a; Van den Heuvel, 2007). In reality, shocks to these variables as a result of monetary policy operations are accompanied by transactions between the central bank and commercial banks. These transactions result in *first-round* impacts on banks by altering at least two items on their balance sheets. By recording these multiple balance sheet changes in accordance with accounting rules, the BSA provides a complete and realistic description of a monetary policy operation as opposed to a proxy for the operation.

Lastly, the BSA enables us to identify the effects of each of the multiple balance sheet changes on BBS capacities. Each individual effect can be positive or negative. The positive effects increase balance sheet capacity, whereas the negative effects decrease it. Moreover, the positive effects will increase and the negative effects will remain unchanged as the stringency of regulations decreases.

This study examines eight monetary policies. As the BSA indicates, it is important to determine which balance sheet items are affected by the monetary policy operation. Accordingly, the eight monetary policy operations are categorized into two groups. Operations in the first group do not involve the bank's holdings of risky securities. This group consists of six monetary policies: outright purchases and sales of Treasury securities, repos, discount window lending, reverse repurchase agreements (RRPs), the term deposit facility, and interest payments on reserves (repos and discount window lending secured by risky securities as collateral belong to the second group). First, the outright purchases and sales of Treasury securities, RRP transactions, and term deposit facility operations have no impact on BBS capacities. Second, repo transactions and discount window lending only negatively affect BBS capacities. Although these monetary policy operations provide liquidity to banks, they reduce their balance sheet capacities. Third, interest payments on reserves simultaneously affect bank reserves and capital. The two impacts can have opposite effects on the BBS capacities, i.e., a positive effect accompanied by a negative effect. The effect of interest payments on reserves is strongest among the six monetary policy operations.

I then turn to studying the effects of the second group. Operations in the second group change the bank's holdings of risky securities. This group comprises two policies. One is that the central bank purchases risky securities, and the other is that the central bank expands the range of eligible collateral for repos or discount window lending.[3]

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[3] The two policies are frequently regarded as unconventional monetary policies (Borio & Disyatat, 2010). The term "unconventional monetary policy" is not used in this paper for

Both policies impact BBS capacities positively. The results are consistent with the stylized fact that the central bank's purchases of risky securities have much stronger effects on lending than the purchases of Treasury securities (Chakraborty et al., 2020; Luck & Zimmermann, 2020; Rodnyansky & Darmouni, 2017). These positive effects, unlike those caused by interest payments on reserves, result from the risk reduction effects of the two policies. They produce the risk reduction effects by substituting risk-free reserves for risky securities. Meanwhile, repo transactions or discount window lending collateralized by risky securities generate the same negative effects as those generated by repo transactions or discount window lending collateralized by Treasury securities.

Finally, this study specifies a transmission mechanism of monetary policy. This channel can be called a BBS capacity channel. Monetary policy operations change the BBS status. As a result, the bank's risk measured by a regulation changes, thereby altering its balance sheet capacity as determined by the regulation. A monetary policy operation may have a negative effect, a positive effect, or both on BBS capacity via the BBS capacity channel. A positive (negative) effect indicates that a monetary policy tool expands (contracts) the BBS capacity, subject to regulation. In other words, the interaction between a monetary policy instrument and a bank regulation determines the impact of the policy on the BBS capacity. Specifically, only interest payments on reserves have the effect of expanding balance sheet capacity as determined by any of

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two reasons. First, the distinction between conventional and unconventional monetary policies is blurring (Borio & Zabai, 2018). Second, the BSA offers a uniform method to examine both conventional and unconventional monetary policies. Therefore, distinguishing between conventional and unconventional monetary policies is unnecessary.

the regulations. Under the CAR, LCR, and NSFR, purchases of risky securities result in expansionary effects. Repo transactions and discount window lending secured by risky securities only have expansionary effects under the LCR. Other combinations of monetary policy operations and regulations have either no effects or negative effects.

The remainder of this paper is organized as follows. Section 2 reviews the literature. Section 3 describes the basic model. Section 4 examines the effects of monetary policies on the BBS capacity. Section 5 extends the basic model to discuss the monetary policies that involve the bank's holdings of risky securities. Section 6 concludes the paper.

2. Literature review

This study builds on the burgeoning recent literature on the mechanism of bank credit creation. The perspective of bank credit creation has become more widely accepted in mainstream economics (Borio, 2019; Goodhart, 2017; Jakab & Kumhof, 2015; Li & Wang, 2020; McLeay et al., 2014; Werner, 2014a, 2014b). Consistent with this viewpoint, the BSA is developed to analyze the behavior of banks, including their credit supply and risk management (Adrian et al., 2019; Adrian & Shin 2010a, 2010b, 2011, 2014). Furthermore, Bezemer (2010, 2016) explains the effectiveness and advantages of the BSA for analyzing monetary and banking systems.

This study uses Basel III regulations to measure bank risk and determine balance sheet capacities. Several recent studies, including Li et al. (2017), Xing et al. (2020), and Xiong et al. (2020), solve for bank lending under Basel III regulations using the BSA. Particularly, Li (2022) develops a more sophisticated model that incorporates bank interest payments and a comprehensive description of the LCR. These studies consider the CAR, LCR, LR, and NSFR as regulatory constraints of banks and thus show credit supply with predetermined reserves and capital. Relative to the aforementioned literature, this study investigates the effects of monetary policy on balance sheet capacity using the BSA. Two major contributions are made. First, the paper clarifies the relations between regulatory risk management tools, risk-taking capacity, and balance sheet capacity. A bank regulation acting as a risk management constraint determines a bank's risk-taking capacity. Subsequently, the risk-taking capacity yields a BBS capacity. Second, the model offers accounting descriptions of monetary policy operations. Using accounting descriptions, the balance sheet model identifies the impacts of each BBS change as a result of a monetary policy operation on the BBS capacity. The BSA identifies the effects by developing a uniform accounting approach to credit supply, bank regulations, and monetary policy operations.

This study examines monetary policy and proposes a BBS capacity channel of monetary policy. The BBS capacity channel is based on the BBS status and risk management. Therefore, the channel is related to the BBS channel (Jiménez et al., 2012; Kashyap & Stein, 1995; Kashyap & Stein, 2000), bank capital channel (Van den Heuvel, 2002; Van den Heuvel, 2007), deposits channel (Drechsler et al., 2017), and risk-taking channel (Borio & Zhu, 2012). The BBS channel emphasizes the role of the BBS status in the transmission of monetary policy. The bank capital channel reveals that a bank's capital adequacy affects its credit supply. The deposits channel illustrates the relation between deposit spreads and outflows and the effects of deposit outflows on credit supply. Finally, the risk-taking channel operates as a result of the impacts of monetary policy on bank risk perceptions and risk tolerance. According to these four monetary policy transmission channels, monetary policy-induced changes in policy rates constitute monetary policy shocks. Through these channels, policy-induced changes in policy rates affect the bank credit supply. In addition, the BBS capacity channel is also related to early studies of the bank lending channel, which consider monetary policy as a shock to reserves (Bernanke, 2007; Bernanke & Blinder, 1988; Bernanke & Gertler, 1995).[4] However, the present study does not simplify monetary policy as a shock to a single variable, such as policy rates or reserves. Instead, I capture the reality of monetary policy operations using accounting descriptions. The accounting description of a monetary policy operation allows us to distinguish between the different effects of different balance sheet changes resulting from the policy. In this manner, this study shows a more complete analysis of the effects of monetary policy operations.

The work of Bech and Keister (2017), who develop a balance sheet model to analyze (i) central bank purchases and sales of Treasury securities and (ii) central bank repos and lending, is a rare exception to the aforementioned literature on monetary policy. Their study solves the bank's demand for reserves under the LCR constraint and examines the effect of the LCR on the interbank rate. Instead of credit supply or balance sheet capacity, their model focuses on bank reserve and liquidity management. Moreover, they present only the accounting analyses of two traditional monetary policies and a liquidity regulation. Rezende et al. (2021) extend Bech and Keister's (2017) model to provide the BSA to the term deposit facility. Unlike these two papers, my model focuses on the credit and money supply processes using reserves and capital as predetermined variables. I examine how monetary policies affect balance sheet capacities as opposed to interbank rates. Another difference is that the present study discusses capital and liquidity regulations and eight monetary policies that influence

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[4] Several additional papers in the literature on bank lending view monetary policy as shocks to short-term rates (Bernanke & Gertler, 1995; Disyatat, 2011; Kashyap & Stein, 1994). As a result, changes in short-term interest rates affect banks' financing costs, thereby influencing bank lending via monetary policy.

bank capital, liquidity, or portfolio risk. Using a BBS analysis, Xiong and Wang (2022) investigate the impacts of monetary policy under regulations on balance sheet capacity. This research is more closely related to the present study. However, their model deviates from the BSA. They define monetary policy operations as shocks to bank reserves only. Therefore, their model fails to develop accounting descriptions of monetary policy operations, the core of the BSA to examining monetary policy. This indicates an insufficient description of monetary policy operations. In contrast, my model uses the BSA to provide an exhaustive accounting description of monetary policy operations.

Additionally, some studies have discussed the effects of monetary policy, strongly emphasizing the role of BBSs. For example, Martin et al. (2016) introduce the notion of BBS costs to explain why banks with large reserves may have no incentive to increase their lending. Furthermore, Martin et al. (2019) show the optimal supply of reserves subject to BBS costs when the central bank pays interest on reserves and reduces reserves via RRPs. In lieu of emphasizing the impacts of BBS costs on balance sheet expansion, the present work demonstrates the effects of monetary policy on BBS items, followed by changes in balance sheet capacities subject to regulatory constraints. Diamond et al. (2023) also propose a balance sheet model and examine the impacts of reserve injections induced by large-scale asset purchases. Their empirical analysis corroborates my result that central bank reserve injections decrease the balance sheet capacity under the LR. Their theoretical framework, however, does not include accounting analyses of the process and effect of central bank asset purchases.

The present study points out the risk reduction effect of central bank purchases of risky securities. This finding contributes to the literature examining how central bank large-scale asset purchases affect bank lending (Chakraborty et al., 2020; Luck &

Zimmermann, 2020; Rodnyansky & Darmouni, 2017). As the growing empirical literature shows, the first and third rounds of large-scale asset purchases significantly increase lending because they include purchases of mortgage-backed securities; by contrast, the second round of large-scale asset purchases does not significantly impact lending because they involve purchases of only Treasuries. The study's theoretical analyses explain this stylized fact further. The central bank's purchase of risky securities, such as mortgage-backed securities, increases banks' balance sheet capacities by reducing their portfolio risk. However, purchases of risk-free securities (Treasuries) do not affect BBS capacities.

3. The model

Using the BSA, I develop a banking model. First, I show the BBS and describe the concepts and determinants of banks' risk and BBS capacity. Second, the balance sheet model provides accounting descriptions of monetary policy operations. These lay the groundwork for research into the effects of monetary policy operations on balance sheet capacity. This balance sheet model implies that credit and money are dynamic during balance sheet expansion or contraction, whereas bank equity behaves according to a predetermined variable (Adrian & Shin 2010a, 2010b, 2011, 2014; Li 2022). It follows that Modigliani and Miller's (1958) theorem does not apply to banks. This is a distinctive feature of the BSA.

3.1. The basics of credit supply

Banks supply credit while they bear risk. Owing to the supply of credit, banks are exposed to several risks and must thus manage these risks. Although different banks may use different risk management tools, the risk management instruments they must use are those mandated by regulators (i.e., bank regulations). The Basel III agreement has established the existing international framework for bank regulations. According to Basel III, the risks taken by banks can be classified into insolvency or liquidity risk; therefore, Basel III proposed two capital regulations, the CAR (Basel Committee on Banking Supervision, 2011) and LR (Basel Committee on Banking Supervision, 2014a), and two liquidity regulations, LCR (Basel Committee on Banking Supervision, 2013) and NSFR (Basel Committee on Banking Supervision, 2014b). The rules of the CAR, LR, LCR, and NSFR regulations are briefly outlined as follows.

Capital adequacy ratio. The CAR is a risk-based capital regulation. The CAR requires banks to have adequate capital as capital buffers to protect against capital losses such as credit defaults and asset price declines. The CAR is defined as

$$\frac{Capital}{Total\ risk\text{-}weighted\ assets} \geq car, \tag{1}$$

where the numerator is the capital of the bank and the denominator is the sum of the products of the bank assets and their risk weights. Moreover, car is the minimum required CAR.

Leverage ratio. The LR is a non-risk-based capital regulation that acts as a backstop for the CAR. The LR imposes a constraint on the accumulation of bank leverage. The LR is defined as

$$\frac{Capital\ measure}{Exposure\ measure} \geq lr, \tag{2}$$

where the capital measure refers to bank capital, considered as a capital buffer, and the exposure measure is defined as the sum of on- and off-balance sheet exposures. The minimum required LR is given by lr.

Liquidity coverage ratio. The LCR is a short-term liquidity requirement. The LCR requires banks to hold sufficient high-quality liquid assets (HQLAs) as liquidity buffers against their net cash outflows at 30 days in times of stress. The minimum required LCR is denoted by lcr. Subsequently, LCR can be written as

$$\frac{\textit{High-quality liquid assets}}{\textit{Net cash outflows over 30 calendar days}} \geq lcr, \tag{3}$$

where net cash outflows over 30 calendar days are given by

$$\textit{Cash outflows} - \min(Cash\ inflows,\ 0.75 \times Cash\ outflows). \tag{4}$$

HQLAs include reserves and high-quality liquid securities, such as Treasury securities. Cash outflows occur from expected deposit run-off, deposit interest payments, and dividend payments, among others. Cash inflows result from expected principal loan repayments, interest income, and other sources.

Net stable funding ratio. The NSFR is a long-term liquidity requirement that complements the LCR. It ensures that banks maintain stable funding profiles for a 1-year period. The NSFR requires banks' available stable funding (ASF) as a liquidity buffer to meet the required stable funding (RSF). The NSFR is defined as

$$\frac{\textit{Available stable funding}}{\textit{Required stable funding}} \geq nsfr, \tag{5}$$

where $nsfr$ denotes the minimum required NSFR. ASF is the sum of liabilities and capital weighted by their ASF factors. The ASF factor increases as the funding source corresponding to the factor becomes more stable. For example, the ASF factor for bank capital, which is the most stable funding source, is 100%. Similarly, the RSF is determined by the weighted sum of assets. An RSF factor is assigned to each asset; it decreases as the corresponding asset's liquidity increases. For instance, the RSF factor for reserves and Treasury securities is 0.

3.2. The balance sheet approach to credit supply and balance sheet capacity

First, I use the BSA to understand the credit supply process. The BSA describes the credit supply process as banks' creation of credit and money, thereby expanding their balance sheets. Banks create deposits when they make loans. Moreover, bank deposits are accepted and used as money (Bezemer, 2016; Li & Wang, 2020; McLeay et al., 2014; Werner, 2014b). Therefore, I use the terms “money” and “(bank) deposits” interchangeably throughout the article. The BBS is shown in Figure 1. [5]

[Insert Figure 1 here]

The balance sheet presents credit C, reserves R, Treasury securities TS, money M, and equity E. The supply of credit expands, and the repayment of credit contracts the balance sheet, as illustrated in Figure 2.

[Insert Figure 2 here]

Meanwhile, the items on the BBS satisfy the BBS identity:

$$C + R + TS = M + E. \tag{6}$$

Second, from the perspective of the balance sheet, a bank regulation imposes a risk management restriction on the balance sheet expansion. A regulatory constraint entails a method for measuring a specific risk taken by banks and establishes a risk limit. To determine the risk measurement methods and limits on bank risk, I can rewrite CAR in equation (1), LR in equation (2), LCR in equation (3), and NSFR in equation (5) as follows:

- CAR:

$$\frac{\textit{Total risk-weighted assets}}{\textit{Capital}} \leq \frac{1}{car}. \tag{7}$$

- LR:

$$\frac{\textit{Exposure measure}}{\textit{Capital measure}} \leq \frac{1}{lr}. \tag{8}$$

[5] To facilitate illustration, the balance sheets presented in this paper are highly stylized: the amounts of balance sheet items shown do not correspond to the amounts actually held on bank balance sheets.

- LCR:

$$\frac{\textit{Net cash outflows over 30 calendar days}}{\textit{High-quality liquid assets}} \leq \frac{1}{lcr}. \tag{9}$$

- NSFR:

$$\frac{\textit{Required stable funding}}{\textit{Available stable funding}} \leq \frac{1}{nsfr}. \tag{10}$$

As equations (7)–(10) suggest, on their left-hand sides, the ratios assess risks to banks; on their right-hand sides, the reciprocals of the minimum required ratios can be considered risk limitations. The limits are referred to as the risk-taking capacities of banks. Meanwhile, the ratios on the left-hand sides of equations (7)–(10) may increase if banks extend credit and, consequently, take greater risk. When the ratio reaches the risk-taking capacity, the banks have undertaken the maximum amount of risk. Simultaneously, their credit supply reaches a limit, which is referred to as balance sheet capacity. [6] Note that the balance sheet capacity represents the bank's capability to supply credit rather than the actual amount of credit supply. When banks lend at their balance sheet capacities, the regulatory constraint is binding, meaning that the regulatory constraints in equations (7)–(10) hold with equality.[7] Additionally, the BBS identity in equation (6) becomes

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[6] Strictly speaking, this definition of balance sheet capacity should be called balance sheet capacity with respect to credit. This is because in addition to providing credit, there are other processes for banks to supply funds and grow their balance sheets, such as purchasing securities from households, non-financial firms, and non-bank financial institutions (Li & Wang 2020). Therefore, it is also reasonable to define balance sheet capacity with respect to securities or a mix of credit and securities, which is left for future research.

[7] Indeed, the regulatory constraints holding equality are first-order conditions of the bank's regulatory-bound maximization problems. See Li (2022) for further information.

$$BSC + R + TS = M + E. \tag{11}$$

3.3. Balance sheet capacities under regulations

First, I present the balance sheet capacity under the CAR. According to the balance sheet shown in Figure 1, the bank capital is equal to E. As bank reserves and Treasury securities are risk-free, their risk weights are equal to 0. The risk weight for credit is denoted by γ_C. The total risk-weighted assets are then equal to $\gamma_C \cdot C$. I denote the balance sheet capacity under the CAR by BSC_{CAR}. When banks reach the balance sheet capacity, the CAR constraint in equation (7) becomes

$$\frac{\gamma_C BSC_{CAR}}{E} = \frac{1}{car}. \tag{12}$$

Second, similar to the analysis of the CAR, the LR constraint in equation (8) can be expressed as follows. The capital measure is equal to E; the exposure measure is the sum of on- and off-balance sheet assets and equal to $BSC_{LR} + R + TS$, where BSC_{LR} is the balance sheet capacity under the LR. Accordingly, the binding LR constraint is

$$\frac{BSC_{LR} + R + TS}{E} = \frac{1}{lr}. \tag{13}$$

Third, I look at the LCR. From the balance sheet in Figure 1, the HQLAs consist of reserves and Treasury securities:

$$HQLAs = R + TS. \tag{14}$$

Bank cash outflows arise from deposit run-off and dividend payments. I denote the 30-day deposit rate, dividend yield, and run-off rate for deposits by i_D, i_E, and α, respectively. Then, the following cash outflows are obtained:

$$OF = (\alpha + i_D)M + i_E E. \tag{15}$$

Loan principal and interest payments contribute cash inflows. Moreover, a bank's HQLAs increase when receiving cash or deposits transferred from other banks. Let us assume that a fraction μ of loans are repaid within 30 days, and a fraction κ of loans are repaid by cash or by the deposits transferred from other banks. Further, the balance sheet capacity under the LCR is denoted by BSC_{LCR}. Then, when banks lend to their capacities, the cash inflows IF are follows:

$$IF = \kappa(\mu + i_L)BSC_{LCR}. \tag{16}$$

LCR has two scenarios, as indicated in equation (4). Using equations (15) and (16), we have the condition for the scenario with low cash flow exposure $IF \geq 0.75OF$:

$$\kappa(\mu + i_L)BSC_{L-LCR} \geq 0.75((\alpha + i_D)M_{L-LCR} + i_E E). \tag{17}$$

This scenario is labeled L-LCR with the balance sheet capacity BSC_{L-LCR} and deposits M_{L-LCR}. Substituting equations (14) and (15) into equations (4) and (9), we obtain the following binding LCR constraint in scenario L-LCR:

$$\frac{0.25((\alpha + i_D)M_{L-LCR} + i_E E)}{R + TS} = \frac{1}{lcr}. \tag{18}$$

In contrast, the scenario with high cash flow exposure $IF < 0.75OF$ is labeled H-LCR. Using equations (15) and (16), we can rewrite $IF < 0.75OF$ as

$$\kappa(\mu + i_L)BSC_{H-LCR} < 0.75((\alpha + i_D)M_{H-LCR} + i_E E), \tag{19}$$

where BSC_{H-LCR} and M_{H-LCR} are the balance sheet capacity and deposits associated with the H-LCR scenario, respectively. By substituting equations (14)–(16) into equations (4) and (9), we obtain the binding LCR constraint in the H-LCR scenario:

$$\frac{(\alpha + i_D)M_{H-LCR} + i_E E - \kappa(\mu + i_L)BSC_{H-LCR}}{R + TS} = \frac{1}{lcr}. \tag{20}$$

Fourth, I demonstrate the balance sheet capacity under the NSFR. The RSF factors for reserves and Treasury securities are 0. If banks reach balance sheet capacity BSC_{NSFR} and corresponding deposits M_{NSFR}, then, based on the balance sheet in Figure 1, the binding definition of NSFR in equation (10) becomes

$$\frac{\phi_C BSC_{NSFR}}{\beta M_{NSFR} + E} = \frac{1}{nsfr}, \tag{21}$$

where β denotes the ASF factor for deposits and ϕ_C denotes the RSF factor for credit.

Multiple balance sheet capacities exist when various regulations are in effect. Each balance sheet capacity is paired with a regulatory scenario that specifies a risk management strategy and risk-taking capacity. Balance sheet capacities before the implementation of monetary policy are determined by the binding CAR constraint (12), LR constraint (13), L-LCR constraint (18), H-LCR constraint (20), and NSFR constraint (21). These regulatory constraints are combined with the balance sheet identity in equation (11) to show the balance sheet capacities in Table 1.

[Insert Table 1 here]

Furthermore, we can simplify the cash flow condition in equation (17) by using the L-LCR capacity and the balance sheet identity in equation (11). The loan rate, deposit rate, and dividend yield are small terms and in the order of magnitude of 10^{-j}, whereas bank reserves and equity are large terms and in the order of magnitude of 10^{Q}. Moreover, Q and j are positive, and Q is significantly larger than j. Retaining only the highest-order terms yields the cash flow condition for the L-LCR scenario as follows:

$$\kappa(\mu + i_L) \geq 0.75(\alpha + i_D). \tag{22}$$

Similarly to the derivation of equation (22), using equation (11) and the H-LCR balance sheet capacity, we can simplify the cash flow condition for the H-LCR scenario in equation (19) to

$$\kappa(\mu + i_L) < 0.75(\alpha + i_D). \tag{23}$$

3.4. Accounting descriptions of monetary policy operations

Having shown balance sheet capacities subject to bank regulations, we need to study how monetary policy operations affect the BBS status. This section provides the key feature of the BSA for examining monetary policy: using the balance sheet to describe policy operations. The central bank conducts monetary policy operations by trading with banks. Multiple balance sheet items are affected simultaneously by a transaction. The BSA provides a comprehensive accounting description of a policy operation by recording its simultaneous changes to multiple balance sheet items. This accounting description thus accurately reflects the reality of policy operations.

Outright purchases and sales of Treasury securities. Permanent OMOs include outright purchases and sales of Treasury securities. OMOs are a traditional instrument of monetary policy for adjusting the quantity of bank reserves and thus the policy rate. Through the execution of these permanent OMOs, the central bank buys or sells securities, such as Treasuries. Changes in the BBS caused by the central bank's outright purchases or sales of Treasury securities are depicted in Figure 3.

[Insert Figure 3 here]

Suppose that the central bank purchases Treasury securities from a bank. Let ΔTS be the value of the purchased Treasury securities. The following balance sheet changes then occur: the decrease in the value of the bank's holdings of Treasury securities, ΔTS, leads to an equal increase in its reserves.

Repurchase agreements and discount window lending. Repo transactions are temporary OMOs. However, discount window lending is an additional monetary policy instrument; the central bank can use it to supply reserves to individual banks. Both repos and discount window loans can be viewed as bank borrowings from the central bank, along with banks using Treasury securities as collateral to obtain reserves. These two monetary policy operations lead to similar changes in the BBS. They can be analyzed in the same way as with the BSA. Figure 4 describes changes in the BBS resulting from a repo transaction or discount window lending.

[Insert Figure 4 here]

A repo or discount window borrowing is added to the liability side of the BBS. That is, repos or discount window borrowings are increased by ΔCB. On the asset side, the bank's reserves are also increased by ΔCB. Meanwhile, the bank must pledge collateral. Its Treasury security holdings are divided into two groups: (i) unencumbered and (ii) pledged as collateral and encumbered. The value of the pledged Treasury securities equals that of the repo or discount window borrowing, ΔCB.

Reverse repurchase agreements. An RRP transaction is also a temporary OMO and is the opposite of a repo. That is, an RRP can be seen as the bank lending to the central bank. Thus, the bank lends reserves to and receives collateral from the central bank. Figure 5 illustrates the changes in the BBS that result from an RRP operation.

[Insert Figure 5 here]

On the asset side of the BBS, lent reserves are subtracted from the reserve account and recorded as an RRP. This results in a decrease in reserves and an equal increase in RRPs, denoted by ΔRRP. The Treasury securities that the central bank pledges as collateral remain on the central bank's balance sheet and do not appear on the BBS.

The term deposit facility. Bank reserves can also be managed by the central bank using the term deposit facility, through which the central bank provides banks with term deposits. The reserves placed in term deposits are removed from the bank's reserve account. In doing so, the central bank drains reserves from the banking system. In addition, the operations of the term deposit facility include an early withdrawal feature: banks can withdraw their reserves before maturity. Figure 6 shows how the term deposit facility operation affects a BBS.

[Insert Figure 6 here]

A term deposit facility operation results in a term deposit item, ΔTD, on the asset side of the balance sheet. The reduction in bank reserves equals the amount of the term deposit.

Interest payments on reserves. The interest payment on reserve balances is a monetary policy instrument through which banks earn interest on reserves held in accounts at the central bank. The interest on reserve balances (IORB) rate refers to the interest rate paid. Figure 7 shows the balance sheet adjustments caused by the central bank's payment of interest on reserves.

[Insert Figure 7 here]

The central bank injects reserves into the banking system by paying interest on reserves. As a result, bank reserves increase by an amount equal to the interest paid by the central bank. Simultaneously, the increase in reserves must increase equity by the same amount. I denote the IORB rate by i_{IORB}. We then see that the increases in reserves ΔR and in equity ΔE equal interest payments on reserves, $i_{IORB}R$.

4. How monetary policy operations affect balance sheet capacity

Section 3.3 presents the determinants of balance sheet capacities; Section 3.4 provides accounting descriptions of monetary policy operations. The BSA enables us to consider simultaneous changes in multiple balance sheet items caused by policy operations and to differentiate the effects of multiple balance sheet changes. This section solves for balance sheet capacities following monetary policy operations using the accounting descriptions of monetary policy operations. The differences in balance sheet capacities after and before monetary policy can then be used to determine the effects of monetary policy. Finally, these effects reflect the existence of a BBS capacity channel of monetary policy.

Due to changes in the BBS in response to monetary policy operations, the risk measures proposed by regulations, or the left-hand sides of the CAR in equation (7), LR in equation (8), LCR in equation (9), and NSFR in equation (10), may also change. However, risk-taking capacities, which are on the right-hand sides of the constraints, are set by regulations and do not change. Consequently, the constraints that include the impact of monetary policy on the balance sheet yield the balance sheet capacities after monetary policy shocks.

In examining the effects of monetary policy, I make three assumptions. The first is about banks' reserve management. Bank reserves are primarily injected by the central bank; banks passively receive reserves (Keister & McAndrews, 2009). This means that banks have a very limited ability to actively manage their reserves. Therefore, for simplicity, the model does not include banks' active management of their reserves. The second assumption concerns banks' investment behavior. Recent empirical studies reveal that a small fraction of banks with greater securities trading expertise prefer buying fire-sold securities to supplying credit during crises (Abbassi et al., 2016; Vinas, 2021). Conversely, banks prefer to supply credit rather than trade securities during normal times (Peydró et al., 2021; Vinas, 2021). In general, as the empirical evidence shows, banks are more specialized in providing credit. Accordingly, the model assumes that banks have a stable preference for credit supply over securities trading. The third assumption is that the model mutes the effects of monetary policy on asset returns. This is because the model focuses on the *first-round* impacts of monetary policy implementation—monetary policy shocks to the BBS. Subsequently, these BBS shocks influence banks' portfolio choices. To adjust their portfolios, banks must buy or sell securities or adjust credit supply. As a result, the returns on those assets may change. I abstract from the resulting changes in asset returns to isolate the effects of monetary policy shocks to the BBS.

4.1. Outright purchases and sales of Treasury securities

Panel B of Figure 3 shows the BBS changes caused by the central bank's purchases or sales of Treasury securities. However, both the risk weights and the RSF factors for reserves and Treasury securities are 0. Moreover, under the LCR, both qualify as HQLAs. Accordingly, reserves are a perfect substitute for Treasury securities under all applicable regulations. As a result, the binding CAR constraint (12), LR constraint (13), L-LCR constraint (18), H-LCR constraint (20), and NSFR constraint (21) do not change. That is, outright purchases or sales of Treasury securities do not change the balance sheet capacities shown in Table 1. These monetary policy operations have no impact on the BBS capacities.

4.2. Repurchase agreements and discount window lending

Panel B of Figure 4 is the BBS that includes a repo with the central bank or a discount window borrowing. Let us start by rewriting the CAR constraint (12), LR constraint (13), L-LCR constraint (18), H-LCR constraint (20), and NSFR constraint (21) according to Panel B of Figure 4. Because the risk weight for reserves is 0, the repo transaction or discount window borrowing does not lead to changes in the CAR risk assessment. For the NSFR, repos and discount window borrowings belong to banks' funding sources. However, the maturity of the repo or discount window borrowing is short (no more than 90 days). Their ASF factors are 0 as a result. In summary, a repo transaction or discount window borrowing does not affect the balance sheet capacity subject to the CAR or NSFR, as shown in Table 1.

In contrast, the exposure measure increases within the LR risk assessment. This is because banks must pledge Treasury securities as collateral, but they should still be accounted for in the exposure measure. Meanwhile, changes in repos or discount window borrowings ΔCB raise reserves from R to $R + \Delta CB$. Next, I turn to the LCR.

Despite the increase in reserves, the repo transaction or discount window borrowing does not increase HQLAs in the LCR; the increase in reserves accompanies an equal reduction in the value of unencumbered Treasury securities. Meanwhile, a repo or discount window borrowing as a liability leads to an increase in cash outflows. Consequently, the cash outflows in equation (15) become

$$OF = (\alpha + i_D)M_{LCR}^{CB} + \omega(1 + i_{CB})\Delta CB + i_E E, \tag{24}$$

where M_{LCR}^{CB} is the deposits corresponding to the balance sheet capacity after the repo transaction or discount window borrowing, i_{CB} denotes the repo or discount window borrowing rate, and ω is the run-off rate for the repo or discount window borrowing. The run-off rate $\omega = 1$ if the maturity of the repo or discount window borrowing is less than or equal to 30 days, and $\omega = 0$ if the maturity is longer than 30 days.

Using the above influences on the LR and LCR, the LR and LCR constraints after a repo transaction or discount window borrowing are obtained as follows.

Leverage ratio. By substituting $R + \Delta CB$ for R in the binding LR constraint given by equation (13), I obtain the following constraint after the repo transaction or discount window borrowing:

$$\frac{BSC_{LR}^{CB} + R + \Delta CB + TS}{E} = \frac{1}{lr}, \tag{25}$$

where BSC_{LR}^{CB} denotes the balance sheet capacity after the repo transaction or discount window borrowing. Equation (25) yields

$$BSC_{LR}^{CB} == \frac{E}{lr} - R - TS - \Delta CB. \tag{26}$$

Liquidity coverage ratio. The repo transaction or discount window borrowing causes the following three changes to the LCR constraints: (i) reserves R are replaced by $R + \Delta CB$; (ii) Treasury securities worth ΔCB are pledged as collateral and encumbered; and (iii) cash outflows in equation (15) are replaced by equation (24). Then, the L-LCR constraint in equation (18) becomes

$$\frac{0.25((\alpha + i_D)M_{L-LCR}^{CB} + \omega(1 + i_{CB})\Delta CB + i_E E)}{R + TS} = \frac{1}{lcr}. \tag{27}$$

The balance sheet identity is necessary to determine the balance sheet capacity. As the repo or discount window borrowing increases the asset and liability sides of the balance sheets by the same amount, the balance sheet identity in equation (11) still holds. Together with equation (11), equation (27) yields the balance sheet capacity after the repo transaction or discount window borrowing:

$$BSC_{L-LCR}^{CB} = \frac{\big(4 - lcr(\alpha + i_D)\big)(R + TS) + lcr(\alpha + i_D - i_E)E}{lcr(\alpha + i_D)} - \frac{\omega(1 + i_{CB})\Delta CB}{(\alpha + i_D)}. \tag{28}$$

Similarly, the H-LCR constraint in equation (20) changes to

$$\frac{(\alpha + i_D)M_{H-LCR}^{CB} + \omega(1 + i_{CB})\Delta CB + i_E E - \kappa(\mu + i_L)BSC_{H-LCR}^{CB}}{R + TS} = \frac{1}{lcr}, \tag{29}$$

where BSC_{H-LCR}^{CB} is the BBS capacity after the repo transaction or discount window borrowing. Then, utilizing equations (11) and (29), I obtain the balance sheet capacity as follows:

$$BSC_{H-LCR}^{CB} = \frac{\big(1 - lcr(\alpha + i_D)\big)(R + TS) + lcr(\alpha + i_D - i_E)E}{lcr\big(\alpha + i_D - \kappa(\mu + i_L)\big)} - \frac{\omega(1 + i_{CB})\Delta CB}{\big(\alpha + i_D - \kappa(\mu + i_L)\big)}. \tag{30}$$

From Table 1 and the balance sheet capacities under LR in equation (26) and LCR in equations (28) and (30), Table 2 presents the effects of repo transactions or discount window lending on BBS capacities.

[Insert Table 2 here]

4.3. Reverse repurchase agreements

Panel B of Figure 5 shows the RRP transaction. According to the rules of the CAR, LR, LCR, and NSFR, we have that (i) the risk weight for RRPs with the central bank is 0; (ii) RRPs are also included in the LR's exposure measure; (iii) since HQLAs can include collateral received, the stock of HQLAs remains unchanged after an RRP transaction; (iv) maturing RRPs secured by Treasuries do not cause cash inflows as measured by the LCR; (v) the RSF factor for RRPs issued by the central bank, with a maturity of 90 days or less, is 0; (vi) the collateral received that is not on the BBS will not be considered in RSF. Therefore, RRP transactions will not change the constraints of CAR, LR, LCR, and NSFR before the RRP transaction; BBS capacities are still provided in Table 1.

4.4. The term deposit facility

Term deposit facility operations are shown in Panel B of Figure 6. When participating in the term deposit facility, banks can access the term deposits offered by the central bank. Afterward, a portion of reserves are converted into term deposits on the asset side of balance sheets. Thus, an increase in banks' term deposits is accompanied by a corresponding decrease in their reserves. But the term deposit facility includes a feature for early withdrawal. Consequently, term deposits will serve as a close substitute for excess reserves (Rezende et al., 2023). Therefore, the risk weight and RSF factor for term deposits are 0, and term deposits are qualified as HQLAs without a haircut. In summary, the operations of the term deposit facility do not influence the BBS capacities; they are still given in Table 1.

4.5. Interest payments on reserves

As Panel B of Figure 7 presents, interest payments on reserves generate simultaneous and equal changes in the reserves and capital of banks. In the following, I compute the balance sheet capacities after interest payments on the reserves. Interest payments on reserves increase reserves from R to $R + \Delta R$, where $\Delta R = i_{IORB} R$ and i_{IORB} is the IORB rate. This impact increases the exposure measure in the LR risk assessment and the HQLAs in the LCR risk assessment. Meanwhile, interest payments on reserves increase the equity from E to $E + \Delta E$, where $\Delta E = i_{IORB} R$. On the one hand, an increase in equity increases the capital identified by the CAR, the capital measure by the LR, and the ASF by the NSFR. On the other hand, an increase in equity increases dividend payments. Thus, the cash outflows specified by the LCR in equation (15) should be rewritten as

$$OF = (\alpha + i_D) M_{LCR}^{IPOR} + i_E E + i_E \Delta E, \tag{31}$$

where M_{LCR}^{IPOR} is the deposits corresponding to the balance sheet capacity after the interest payment on reserves, and $i_E \cdot \Delta E$ on the right-hand side denotes cash flows (dividend payments) resulting from the interest payment on the reserves. Considering the aforementioned influences on regulatory constraints, I can then rewrite the regulatory constraints preceding interest payments on reserves in order to obtain those that follow them. Assuming equality, regulatory constraints after interest payments on reserves yield balance sheet capacities.

Capital adequacy ratio. After interest payments on reserves, the binding CAR constraint (12) becomes

$$\frac{\gamma_C BSC_{CAR}^{IPOR}}{E + \Delta E} = \frac{1}{car}. \tag{32}$$

Solving for the balance sheet capacity BSC_{CAR}^{IPOR}, we have

$$BSC_{CAR}^{IPOR} = \frac{E + \Delta E}{car \cdot \gamma_C}. \tag{33}$$

Leverage ratio. Substituting $R + \Delta R$ for R and $E + \Delta E$ for E into the binding LR constraint (13), we obtain

$$\frac{BSC_{LR}^{IPOR} + R + \Delta R + TS}{E + \Delta E} = \frac{1}{lr}. \tag{34}$$

Then, equation (34) yields the balance sheet capacity:

$$BSC_{LR}^{IPOR} == \frac{E}{lr} - R - TS + \frac{\Delta E}{lr} - \Delta R \tag{35}$$

Liquidity coverage ratio. The interest payment on the reserves changes the LCR constraints by (i) increasing the reserves from R to $R + \Delta R$ and (ii) increasing the cash outflow in equation (15) to that in equation (31). Considering these changes, the constraints under the two LCR scenarios are presented. First, the constraint under the L-LCR scenario given by equation (18) becomes

$$\frac{0.25((\alpha + i_D)M_{L-LCR}^{IPOR} + i_E E + i_E \Delta E)}{R + \Delta R + TS} = \frac{1}{lcr}. \tag{36}$$

To solve for the balance sheet capacity, we need to use the balance sheet identity. The interest payment on the reserves increases the reserves and equity by the same amount; therefore, the balance sheet identity is still given by equation (11). Using equation (36) and the balance sheet identity in equation (11) yields the following balance sheet capacity:

$$BSC_{L-LCR}^{IPOR} = \frac{\big(4 - lcr(\alpha + i_D)\big)(R + TS) + lcr(\alpha + i_D - i_E)E}{lcr(\alpha + i_D)} + \frac{4\Delta R - lcr \cdot i_E \Delta E}{lcr(\alpha + i_D)}. \tag{37}$$

Second, the H-LCR constraint in equation (20) can be rewritten as

$$\frac{(\alpha + i_D)M_{H-LCR}^{IPOR} + i_E E + i_E \cdot \Delta E - \kappa(\mu + i_L)BSC_{H-LCR}^{IPOR}}{R + \Delta R + TS} = \frac{1}{lcr}. \tag{38}$$

Then, using equation (11), I solve for balance sheet capacity as

$$BSC_{H-LCR}^{IPOR} = \frac{\big(1 - lcr(\alpha + i_D)\big)(R + TS) + lcr(\alpha + i_D - i_E)E}{lcr\big(\alpha + i_D - \kappa(\mu + i_L)\big)} + \frac{\Delta R - lcr \cdot i_E \Delta E}{lcr\big(\alpha + i_D - \kappa(\mu + i_L)\big)} \tag{39}$$

Net stable funding ratio. The interest payment on reserves increases the ASF by increasing equity. By substituting $E + \Delta E$ for E in the NSFR binding constraint (21), we obtain

$$\frac{\phi_C BSC_{NSFR}^{IPOR}}{\beta M_{NSFR}^{IPOR} + E + \Delta E} = \frac{1}{nsfr}. \tag{40}$$

Combining equations (40) and (11) yields the following balance sheet capacity:

$$BSC_{NSFR}^{IPOR} = \frac{\beta R + (1 - \beta)E + \beta \Delta R + (1 - \beta)\Delta E}{nsfr \cdot \phi_C - \beta}. \tag{41}$$

Finally, comparing Table 1 with the balance sheet capacities under CAR in equation (33), LR in equation (35), LCR in equations (37) and (39), and NSFR in equation (41), I show the effects of interest payments on the BBS capacities in Table 3.

[Insert Table 3 here]

4.6. Discussion of monetary policy operations' effects on balance sheet capacity

I have examined six monetary policy tools using the BSA. Next, I discuss the effects of the monetary policy operations. Outright purchases and sales of Treasury securities, RRP transactions, and term deposit facility operations do not influence the BBS capacities. In contrast, the BBS capacities are influenced by repo transactions, discount window lending, and interest payments on reserves. Using the BSA to identify and differentiate the effects arising from multiple balance sheet changes, I find that a monetary policy can simultaneously have both negative and positive effects on balance sheet capacities. In response to a monetary policy operation, the positive effect determines the expansion of balance sheet capacities. The negative effect is attributable to the contraction of balance sheet capacities. A monetary policy operation has a positive (negative) effect on the balance sheet capacity subject to regulation because from the perspective of regulation, at least one of the operation's impacts on the BBS reduces (increases) the risk identified by the regulation. One caveat to this discussion is that the effects of monetary policy are imposed on balance sheet capacities, which are derived from binding regulatory constraints. Another caveat is that the results are obtained under the three modeling assumptions.

As shown in Table 2, repo transactions and discount window lending have no effect on balance sheet capacities under the CAR or NSFR, or they negatively affect those under the LR or LCR. A repo transaction or discount window lending induces a reserve injection. As banks do not lend out their reserves, the increase in reserves does not directly raise the ability of banks to supply credit (Keister & McAndrews, 2009; Li & Wang, 2020; McLeay et al., 2014; Werner, 2014a, 2014b). However, the reserve injection can increase the LR and LCR risk measures. The LR aims to control the build-up of banks' leverage by imposing a limit on their leverage. To do so, the exposure measure of the LR takes into account banks' risk-free assets. As a result, the reserve injection increases the LR exposure measure and then reduces the BBS capacity specified by the LR. The purpose of the LCR is to ensure that banks' liquidity buffers can cover their short-term net cash outflows. Banks' liquidity buffers qualified as HQLAs are equal to the sum of reserves and Treasuries. Although a repo transaction or discount window lending injects reserves into a bank, the repo or loan also involves pledging an equal value of unencumbered Treasuries as collateral to the central bank. Thus, a repo transaction or discount window lending does not increase the bank's HQLAs. But a central bank repo or discount window loan must be a debt of the bank.

Repaying the debt leads to a cash outflow from the bank. If the maturity of the repo or discount window borrowing is less than or equal to 30 days, this cash outflow raises the LCR risk measure and then produces negative effects on the BBS capacities determined by the LCR.

In sum, a central bank repo transaction or discount window lending results in negative effects on the BBS capacities associated with the LR or LCR. These negative effects are incompatible with the purpose of a repo transaction or discount window lending, which is to provide liquidity to banks.

In contrast, interest payments on reserves can produce positive and negative effects. Thus, such a monetary policy operation can generate expansionary effects on balance sheet capacities. The interest payment on reserves brings about a capital injection $\Delta E = i_{IORB}R$ and a reserve injection $\Delta R = i_{IORB}R$. As Table 3 indicates, capital injection leads to positive effects on the balance sheet capacities under the CAR and LR. The injection of reserves has positive effects on the balance sheet capacities under the LCR. Both the reserve injection and the capital injection cause a positive effect on the balance sheet capacity under the NSFR. These positive effects are in line with the primary objective of an accommodating monetary policy. In the meantime, we can see detrimental effects on the balance sheet capacities under the LR and LCR. The mechanisms behind these negative effects are interpreted as follows. Due to the interest payment on the reserves, the injected reserves increase the exposure measure of the LR by ΔR; the injection of reserves leads to a reduction in the balance sheet capacity of the LR. On the other hand, the injected capital increases dividend payments, or cash outflows, by $i_E \Delta E$. The increase in cash outflows reduces the capacity of the balance sheet under the LCR.

In conclusion, outright purchases and sales of Treasury securities, RRP transactions, and term deposit facility operations have no effects on BBS capacities. Moreover, policymakers should be cognizant of the negative or contractive effects of repo transactions and discount window lending on the BBS capacities subject to the LR or LCR. It follows that OMOs are not effective in influencing BBS capacities. In contrast, policymakers are permitted to use interest payments on reserves to expand BBS capacity and credit supply under any of the regulations. This result is consistent with the reality of the implementation of the monetary policy. That is, interest payment on reserves is currently the main monetary policy tool in practice (Ihrig et al., 2023). Furthermore, decreasing the stringency of regulations increases risk-taking capacities and improves positive effects, while negative effects remain unaffected. Thus, policymakers can adjust the stringency of the LR or LCR to affect the relative strength of positive and negative effects.

5. Extension to monetary policy operations involving risky securities

The 2008 financial crisis and subsequent Great Recession have prompted extraordinary responses from central banks in major economies (Borio & Disyatat, 2010). For example, they implemented large-scale asset purchases or quantitative easing (Bernanke, 2010; Gagnon et al., 2011; Gertler & Karadi, 2013). Large-scale asset purchases include central bank purchases of risky securities held by banks. This new measure directly influences the risk profile of the BBS. In addition to direct purchases of risky securities, central banks accept risky securities as collateral for repos and discount window lending. In other words, central banks broaden the scope of eligible collateral for central bank repos or discount window lending.

This section extends the basic balance sheet model to examine the two monetary policies that involve risky securities. The extended model is also subject to the three assumptions imposed on the basic model. Figure 8 shows a BBS, including risky securities RS.

[Insert Figure 8 here]

With risky securities, the balance sheet identity in equation (11) will be rewritten as

$$BSC + R + TS + RS = M + E. \tag{42}$$

Assume that the risky securities have a risk weight of γ_{RS} and an RSF factor of ϕ_{RS} and are qualified as HQLAs subject to a haircut hc. Then, from the CAR constraint (12), LR constraint (13), L-LCR constraint (18), H-LCR constraint (20), and NSFR constraint (21), we have the following regulatory constraints with risky securities:

- CAR:

$$\frac{\gamma_C BSC_{CAR} + \gamma_{RS} RS}{E} = \frac{1}{car}; \tag{43}$$

- LR:

$$\frac{BSC_{LR} + R + TS + RS}{E} = \frac{1}{lr}; \tag{44}$$

- L-LCR:

$$\frac{0.25((\alpha + i_D)M_{L-LCR} + i_E E)}{R + TS + (1 - hc)RS} = \frac{1}{lcr}; \tag{45}$$

- H-LCR:

$$\frac{(\alpha + i_D)M_{H-LCR} + i_E E - \kappa(\mu + i_L)BSC_{H-LCR}}{R + TS + (1 - hc)RS} = \frac{1}{lcr}; \tag{46}$$

- NSFR:

$$\frac{\phi_C BSC_{NSFR} + \phi_{RS} RS}{\beta M_{NSFR} + E} = \frac{1}{nsfr}. \tag{47}$$

5.1. Purchases of risky securities

The accounting description of the central bank's acquisition of risky securities held by banks is depicted in Figure 9.

[Insert Figure 9 here]

The central bank substitutes reserves for risky securities during the purchase process. As the decrease in the value of risky securities is equal to the increase in reserves, the balance sheet identity after the purchase of risky securities is still given by equation (42). Denote by ΔRS the value of the risky securities purchased. Let the superscript $PORS$ denote the values of variables (balance sheet capacities and deposits) after the purchase of risky securities. Then, using the CAR constraint (43), LR constraint (44), L-LCR constraint (45), H-LCR constraint (46), and NSFR constraint (47), we have the regulatory constraints after the purchase of risky securities.

- CAR:

$$\frac{\gamma_C BSC_{CAR}^{PORS} + \gamma_{RS}(RS - \Delta RS)}{E} = \frac{1}{car}; \tag{48}$$

- LR:

$$\frac{BSC_{LR}^{PORS} + R + \Delta RS + TS + RS - \Delta RS}{E} = \frac{1}{lr}; \tag{49}$$

- L-LCR:

$$\frac{0.25((\alpha + i_D)M_{L-LCR}^{PORS} + i_E E)}{R + \Delta RS + TS + (1 - hc)(RS - \Delta RS)} = \frac{1}{lcr}; \tag{50}$$

- H-LCR:

$$\frac{(\alpha + i_D)M_{H-LCR}^{PORS} + i_E E - \kappa(\mu + i_L)BSC_{H-LCR}^{PORS}}{R + \Delta RS + TS + (1 - hc)(RS - \Delta RS)} = \frac{1}{lcr}; \tag{51}$$

- NSFR:

$$\frac{\phi_C BSC_{NSFR}^{PORS} + \phi_{RS}(RS - \Delta RS)}{\beta M_{NSFR}^{PORS} + E} = \frac{1}{nsfr}. \tag{52}$$

Combining the regulatory constraints before and after the purchase of risky securities (equations (43)–(47) and equations (48)–(52)) together with the balance sheet identity in equation (42), I obtain its effects on the BBS capacities, which are presented in Table 4.

[Insert Table 4 here]

5.2. The broadening of eligible collateral for repurchase agreements and discount window lending

Figure 10 shows the accounting description of a repo transaction or discount window lending collateralized by risky securities.

[Insert Figure 10 here]

In reference to the analysis of the repo transaction or discount window lending collateralized by Treasury securities presented in Section 4.2, I describe the regulatory constraints subsequently imposed on the BBS containing risky securities. Denote by ΔCB_{RS} changes in repos or discount window loans collateralized by risky securities. The central bank sets the collateral haircut as χ. Therefore, the value of risky securities to be pledged equals $\Delta CB_{RS}/(1-\chi)$. Let the superscript $BOEC$ denote the values of variables (balance sheet capacities and deposits) after the repo transaction or discount window lending. The risk weight and the RSF factor for the risky securities pledged as collateral are still given by γ_{RS} and ϕ_{RS}, respectively. Therefore, a repo transaction or discount window lending collateralized by risky securities leads to no changes in the CAR and NSFR constraints. On the contrary, the reserves borrowed from the central bank increase the LR's exposure measure; LR constraint (44) then becomes

$$\frac{BSC_{LR}^{BOEC} + R + \Delta CB_{RS} + TS + RS}{E} = \frac{1}{lr}. \tag{53}$$

As for the LCR, setting $\Delta CB = \Delta CB_{RS}$ and substituting the HQLAs

$$R + \Delta CB_{RS} + TS + (1-hc)(RS - \frac{\Delta CB_{RS}}{1-\chi}) \tag{54}$$

for the denominator in the L-LCR constraint (27) yield the L-LCR constraint after a repo transaction or discount window lending collateralized by risky securities:

$$\frac{0.25((\alpha + i_D)M_{L-LCR}^{BOEC} + \omega(1 + i_{CB})\Delta CB_{RS} + i_E E)}{R + \Delta CB_{RS} + TS + (1 - hc)(RS - \frac{\Delta CB_{RS}}{1 - \chi})} = \frac{1}{lcr}. \tag{55}$$

Similarly, from equation (29), we have the H-LCR constraint

$$\frac{(\alpha + i_D)M_{H-LCR}^{BOEC} + \omega(1 + i_{CB})\Delta CB_{RS} + i_E E - \kappa(\mu + i_L)BSC_{H-LCR}^{BOEC}}{R + \Delta CB_{RS} + TS + (1 - hc)(RS - \frac{\Delta CB_{RS}}{1 - \chi})} = \frac{1}{lcr}. \tag{56}$$

Combine regulatory constraints before and after a repo transaction or discount window lending collateralized by risky securities (equations (44)–(46) and equations (53), (55), and (56)) and the balance sheet identity in equation (42) to obtain its effects on the BBS capacities of the bank, as shown in Table 5.

[Insert Table 5 here]

5.3. Discussion of monetary policy operations involving risky securities

It is helpful to compare the results regarding the purchase of risky securities with those regarding the purchase of Treasury securities in Section 4.1 to comprehend these results. The only difference between them is that one invests in risk-free securities and the other invests in risky securities. Indeed, the purchase of risk-free securities is an extreme example of the purchase of risky securities where $\gamma_{RS} = hc = \phi_{RS} = 0$. At this time, all the effects of purchasing risky securities shown in Table 4 reduce to 0. This is precisely what I find when the central bank buys Treasury securities. As the comparison shows, the positive impacts on the balance sheet capacities come from the risk reduction effects of the acquisition of risky securities on the BBS. These positive effects are proportional to the risks of the acquired securities, as measured by the CAR, γ_{RS}, LCR, hc, and NSFR, ϕ_{RS}. This means that the degree of risk reduction when the central bank purchases 1 unit of risky securities is proportional to the risks measured by regulations.

The LR is risk-insensitive, so the purchase of risky securities cannot cause a risk reduction effect on the balance sheet capacity under the LR. By contrasting the effects of purchases of risky securities with those of interest payments on reserves, additional insights can be gained. By injecting reserves and capital into banks, the payment of interest on reserves has a positive effect on their balance sheet capacities. As shown in Table 3, ΔE and ΔR represent capital and reserve injections, respectively. Consistent with this interpretation, the effects of purchases of risky securities can be observed as a capital injection, a reserve injection, or both. Purchases of risky securities lead to a capital injection $car \cdot \gamma_{RS} \cdot \Delta RS$ under the CAR, a reserve injection $hc \cdot \Delta RS$ under the LCR, and a combination of a reserve injection $nsfr \cdot \phi_{RS} \cdot \Delta RS$ and a capital injection $nsfr \cdot \phi_{RS} \cdot \Delta RS$ under the NSFR (the impact is divided into the reserve injection effect $(\beta \cdot nsfr \cdot \phi_{RS}/(nsfr \cdot \phi_C - \beta))\Delta RS$ and the capital injection effect $((1 - \beta)nsfr \cdot \phi_{RS}/(nsfr \cdot \phi_C - \beta))\Delta RS$).

As presented in Table 5, broadening eligible collateral for repos and discount window lending has both positive and negative effects. Positive and negative effects are caused by distinct factors. A repo transaction or discount window lending secured by risky securities causes a change in the liability side and a change in the asset side of the BBS. The increase in repos or discount window borrowings on the liability side is denoted by ΔCB_{RS}^{L}, and the increase in reserves on the asset side is denoted by ΔCB_{RS}^{A}. Using ΔCB_{RS}^{L} and ΔCB_{RS}^{A}, I obtain Table 6 to better explain the causes of negative and positive effects.

[Insert Table 6 here]

The terms dependent on ΔCB_{RS}^{L} reflect the negative effects. The cause of the negative effects is that a repo transaction or discount window lending increases the bank's leverage or its exposure to cash outflows. Negative effects occur when banks borrow from the central bank, regardless of whether they use Treasury securities or risky securities as collateral. In other words, ΔCB_{RS}^{L} is responsible for the negative effects; the terms dependent on ΔCB_{RS}^{L} in Table 6 correspond to the adverse effects shown in Table 2, which result from repos and discount window borrowings collateralized by Treasury securities.

On the other hand, terms dependent on ΔCB_{RS}^{A} produce positive effects. As in the discussion of buying risky securities, the positive effects are equivalent to those caused by a reserve injection $((hc-\chi)/(1-\chi))\Delta CB_{RS}^{A}$ under the LCR. The cause of the positive effects is that the use of risky securities as collateral leads to effects of risk reduction on the BBS: bank reserves are substituted for risky securities. The value $(hc-\chi)/(1-\chi)$ represents the degree of risk reduction per unit of repo transaction or discount window lending collateralized by risky securities after collateral haircut χ and liquidity haircut hc are applied. This risk reduction effect has two implications. First, for the central bank repo or lending to produce the desired effects, the collateral haircut must be less than the liquidity haircut. This means that the central bank must bear a part of the risk of the pledged securities by setting the collateral haircut lower than the liquidity haircut for them. Second, the central bank may need to "overvalue" risky securities received as collateral. As

$$\frac{\partial \frac{(hc-\chi)}{(1-\chi)}}{\partial \chi} < 0 \tag{57}$$

indicates, when the central bank is willing to take more risk by setting a lower collateral haircut, central bank repo transactions or lending can generate a greater effect.

To sum up, the above monetary policy effects work through a BBS capacity channel. A central bank purchasing risky securities from banks or providing them liquidity through repos or discount window lending collateralized by risky securities can produce effects consistent with the purpose of an accommodative monetary policy. In addition, these results are subject to the same two caveats as in the discussion on monetary policy operations that do not involve risky securities.

6. Conclusion

One of the most studied areas of monetary economics is the monetary policy transmission mechanism. In recent years, the frameworks for monetary policy and bank regulation have been significantly updated. These developments have reignited an interest in understanding the effects that monetary policy operations have on banks.

This study develops a balance sheet model to examine how monetary policy operations affect BBS capacities. On the one hand, banks are subject to the risk management constraints of the Basel III regulations. Each regulation imposes a risk-taking capacity on banks, or the maximum amount of risk they are permitted to take. Each risk-taking capacity corresponds to a BBS capacity, or the ability of banks to supply credit. On the other hand, monetary policy operations are interpreted as transactions between the central bank and commercial banks. The balance sheet model contains accounting descriptions of these transactions. These accounting descriptions reflect the reality of monetary policy operations and their *first-round* impacts on banks.

I point out a BBS capacity channel that functions as follows. Monetary policy operations change BBS positions. Thus, changes in BBS positions for a given risk-taking capacity lead to changes in balance sheet capacity. Lastly, the effects of monetary policy operations on BBS capacities may be negative, positive, or both.

This study examined eight monetary policies. Interest payments on reserves simultaneously have two different effects on BBS capacities. This is because interest payments on reserves lead to both reserve and capital injections with differing impacts on the BBS. Meanwhile, repo transactions or discount window lending negatively affects BBS capacities. Additionally, outright purchases and sales of Treasury securities, RRP transactions, and term deposit facility operations do not affect BBS capacities. Furthermore, central bank purchases of risk securities and repos or discount window lending collateralized by risky securities positively affect BBS capacity by reducing bank portfolio risk.

These findings provide clear guidance on how to employ monetary policy tools to affect credit supply. By expanding BBS capacity, central bank interest payments on reserves, purchases of risky securities, and repos and lending collateralized by risky securities can be used as expansionary monetary policies. Moreover, when implementing monetary policies, central banks should be aware of the interaction between policy operations and bank regulations. If the stringency of the binding regulation decreases, the positive effects will be enhanced, whereas the negative effects will remain unchanged.

The present paper focuses on balance sheet capacity, which is a fundamental issue in the study of monetary policy effects. Therefore, this study suggests several promising directions for future research. For example, a future paper could account for banks' investment strategies to show how a bank allocates its balance sheet capacity among various assets.

References

Abbassi, P., Iyer, R., Peydró, J.-L., & Tous, F. R. (2016). Securities trading by banks and credit supply: Micro-evidence from the crisis. *Journal of Financial Economics*, *121*(3), 569–594. https://doi.org/10.1016/j.jfineco.2016.05.005

Adrian, T., Estrella, A., & Shin, H. S. (2019). Risk-taking channel of monetary policy. *Financial Management*, *48*(3), 725–738. https://doi.org/10.1111/fima.12256

Adrian, T., & Shin, H. S. (2009). Prices and quantities in the monetary policy transmission mechanism. *International Journal of Central Banking*, *5*(4), 131–142. https://doi.org/10.2139/ssrn.1483825

Adrian, T., & Shin, H. S. (2010a). Financial intermediaries and monetary economics. In B. M. Friedman & M. Woodford (Eds.), *Handbook of Monetary Economics* (Vol. 3A pp. 601–650). Elsevier. https://doi.org/10.1016/B978-0-444-53238-1.00012-

0
Adrian, T., & Shin, H. S. (2010b). Liquidity and leverage. *Journal of Financial Intermediation*, *19*(3), 418–437. https://doi.org/10.1016/j.jfi.2008.12.002
Adrian, T., & Shin, H. S. (2011). Financial intermediary balance sheet management. *Annual Review of Financial Economics*, *3*(1), 289–307. https://doi.org/10.1146/annurev-financial-102710-144915
Adrian, T., & Shin, H. S. (2014). Procyclical leverage and value-at-risk. *The Review of Financial Studies*, *27*(2), 373–403. https://doi.org/10.1093/rfs/hht068
Balasubramanyan, L., & VanHoose, D. D. (2013). Bank balance sheet dynamics under a regulatory liquidity-coverage-ratio constraint. *Journal of Macroeconomics*, *37*, 53–67. https://doi.org/10.1016/j.jmacro.2013.03.003
Basel Committee on Banking, S. (2011). *Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems*. Bank for International Settlements. https://www.bis.org/publ/bcbs189.pdf
Basel Committee on Banking, S. (2013). *Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools*. Bank for International Settlements. https://www.bis.org/publ/bcbs238.pdf
Basel Committee on Banking, S. (2014a). *Basel III Leverage Ratio Framework and Disclosure Requirements*. Bank for International Settlements. https://www.bis.org/publ/bcbs270.pdf
Basel Committee on Banking, S. (2014b). *Basel III: The Net Stable Funding Ratio*. Bank for International Settlements. http://www.bis.org/bcbs/publ/d295.pdf
Bech, M., & Keister, T. (2017). Liquidity regulation and the implementation of monetary policy. *Journal of Monetary Economics*, *92*, 64–77. https://doi.org/10.1016/j.jmoneco.2017.09.002
Bernanke, B. S. (2007). *The financial accelerator and the credit channel*. The Credit Channel of Monetary Policy in the Twenty-first Century Conference, Federal Reserve Bank of Atlanta, Atlanta, Georgia. https://www.federalreserve.gov/newsevents/speech/bernanke20070615a.htm
Bernanke, B. S. (2010). *The Economic Outlook and Monetary Policy*. The Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming. https://www.federalreserve.gov/newsevents/speech/bernanke20100827a.htm
Bernanke, B. S. (2023). Nobel lecture: Banking, credit, and economic fluctuations. *American Economic Review*, *113*(5), 1143–1169. https://doi.org/10.1257/aer.113.5.1143
Bernanke, B. S., & Blinder, A. S. (1988). Credit, money, and aggregate demand. *American Economic Review*, *78*(2), 435–439. https://doi.org/10.1016/S0197-2510(11)70055-9
Bernanke, B. S., & Blinder, A. S. (1992). The federal funds rate and the channels of monetary transmission. *American Economic Review*, *82*(4), 901–921.
Bernanke, B. S., & Gertler, M. (1995). Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspectives*, *9*(4), 27–48. https://doi.org/10.1257/jep.9.4.27
Bezemer, D. J. (2010). Understanding financial crisis through accounting models. *Accounting, Organizations and Society*, *35*(7), 676–688. https://doi.org/10.1016/j.aos.2010.07.002
Bezemer, D. J. (2016). Towards an 'accounting view' on money, banking and the macroeconomy: History, empirics, theory. *Cambridge Journal of Economics*, *40*(5), 1275–1295. https://doi.org/10.1093/cje/bew035
Boivin, J., Kiley, M. T., & Mishkin, F. S. (2010). How has the monetary transmission

mechanism evolved over time? In B. M. Friedman & M. Woodford (Eds.), *Handbook of Monetary Economics* (Vol. 3, pp. 369–422). Elsevier. https://doi.org/10.1016/B978-0-444-53238-1.00008-9

Bolton, P., & Freixas, X. (2006). Corporate finance and the monetary transmission mechanism. *The Review of Financial Studies*, *19*(3), 829–870. https://doi.org/10.1093/rfs/hhl002

Borio, C. (2019). On money, debt, trust, and central banking. *Cato Journal*, *39*, 267–302.

Borio, C., & Disyatat, P. (2010). Unconventional monetary policies: An appraisal. *The Manchester School*, *78*(s1), 53–89. https://doi.org/10.1111/j.1467-9957.2010.02199.x

Borio, C., & Gambacorta, L. (2017). Monetary policy and bank lending in a low interest rate environment: Diminishing effectiveness? *Journal of Macroeconomics*, *54*, 217–231. https://doi.org/10.1016/j.jmacro.2017.02.005

Borio, C., & Zabai, A. (2018). Unconventional monetary policies: A re-appraisal. In P. Conti-Brown & R. M. Lastra (Eds.), *Research Handbook on Central Banking* (pp. 398–444). Edward Elgar Publishing. https://doi.org/10.4337/9781784719227.00026

Borio, C., & Zhu, H. (2012). Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism? *Journal of Financial Stability*, *8*(4), 236–251. https://doi.org/10.1016/j.jfs.2011.12.003

Bruno, V., & Shin, H. S. (2015). Capital flows and the risk-taking channel of monetary policy. *Journal of Monetary Economics*, *71*, 119–132. https://doi.org/10.1016/j.jmoneco.2014.11.011

Cap, A., Drehmann, M., & Schrimpf, A. (2020). Changes in monetary policy operating procedures over the last decade: Insights from a new database. *BIS Quarterly Review*, *December*, 27–39.

Cecchetti, S. G., & Li, L. (2008). Do capital adequacy requirements matter for monetary policy? *Economic Inquiry*, *46*(4), 643–659. https://doi.org/10.1111/j.1465-7295.2007.00085.x

Chakraborty, I., Goldstein, I., & MacKinlay, A. (2020). Monetary stimulus and bank lending. *Journal of Financial Economics*, *136*(1), 189–218. https://doi.org/10.1016/j.jfineco.2019.09.007

De Nicolo, G., Gamba, A., & Lucchetta, M. (2014). Microprudential regulation in a dynamic model of banking. *The Review of Financial Studies*, *27*(7), 2097–2138. https://doi.org/10.1093/rfs/hhu022

Diamond, W., Jiang, Z., & Ma, Y. (2023). The reserve supply channel of unconventional monetary policy. *NBER Working Paper No. 31693, National Bureau of Economic Research*. https://doi.org/10.3386/w31693

Disyatat, P. (2008). Monetary policy implementation: Misconceptions and their consequences. *BIS Working Paper No. 269, Bank for International Settlements*. https://doi.org/10.2139/ssrn.1334134

Disyatat, P. (2011). The bank lending channel revisited. *Journal of Money, Credit and Banking*, *43*(4), 711–734. https://doi.org/10.1111/j.1538-4616.2011.00394.x

Drechsler, I., Savov, A., & Schnabl, P. (2017). The deposits channel of monetary policy. *The Quarterly Journal of Economics*, *132*(4), 1819–1876. https://doi.org/10.1093/qje/qjx019

Fraisse, H., Lé, M., & Thesmar, D. (2020). The real effects of bank capital requirements. *Management Science*, *66*(1), 5–23. https://doi.org/10.1287/mnsc.2018.3222

Francis, W., & Osborne, M. (2009). Bank regulation, capital and credit supply: Measuring the impact of prudential standards. *Occasional Paper Series No. 36, UK Financial Services Authority*.

Gagnon, J., Raskin, M., Remache, J., & Sack, B. (2011). The financial market effects of the Federal Reserve's large-scale asset purchases. *International Journal of Central Banking*, *7*(1), 45–52.

Gambacorta, L., & Shin, H. S. (2018). Why bank capital matters for monetary policy. *Journal of Financial Intermediation*, *35*, 17–29. https://doi.org/10.1016/j.jfi.2016.09.005

Gertler, M., & 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*(S1), 5–53.

Goodhart, C. A. E. (2017). The determination of the money supply: Flexibility versus control. *The Manchester School*, *85*, 33–56. https://doi.org/10.1111/manc.12194

Greenwood, R., Hanson, S. G., Shleifer, A., & Sørensen, J. A. (2022). Predictable financial crises. *The Journal of Finance*, *77*(2), 863–921. https://doi.org/10.1111/jofi.13105

Gropp, R., Mosk, T., Ongena, S., & Wix, C. (2019). Banks response to higher capital requirements: Evidence from a quasi-natural experiment. *The Review of Financial Studies*, *32*(1), 266–299. https://doi.org/10.1093/rfs/hhy052

Ihrig, J., Weinbach, G., & Wolla, S. (2023). How are banks and the Fed linked? Teaching key concepts today. *Review of Political Economy*, *35*(2), 555–571. https://doi.org/10.1080/09538259.2022.2040906

Jakab, Z., & Kumhof, M. (2015). Banks are not intermediaries of loanable funds—And why this matters. *Working Paper No. 529, Bank of England*. https://doi.org/10.2139/ssrn.2612050

Jiménez, G., Ongena, S., Peydró, J. L., & Saurina, J. (2012). Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications. *American Economic Review*, *102*(5), 2301–2326. https://doi.org/10.1257/aer.102.5.2301

Juelsrud, R. E., & Wold, E. G. (2020). Risk-weighted capital requirements and portfolio rebalancing. *Journal of Financial Intermediation*, *41*, Article 100806. https://doi.org/10.1016/j.jfi.2018.10.002

Kashyap, A. K., & Stein, J. C. (1994). Monetary policy and bank lending. In G. N. Mankiw (Ed.), *Monetary Policy* (pp. 221–256). University of Chicago Press.

Kashyap, A. K., & Stein, J. C. (1995). The impact of monetary policy on bank balance sheets. *Carnegie-Rochester Conference Series on Public Policy*, *42*, 151–195. https://doi.org/10.1016/0167-2231(95)00032-U

Kashyap, A. K., & Stein, J. C. (2000). What do a million observations on banks say about the transmission of monetary policy? *American Economic Review*, *90*(3), 407–428. https://doi.org/10.1257/aer.90.3.407

Keister, T., & McAndrews, J. (2009). Why are banks holding so many excess reserves? *Current Issues in Economics and Finance*, *15*, Article 8. https://doi.org/10.2139/ssrn.1543348

King, M. R. (2013). The Basel III net stable funding ratio and bank net interest margins. *Journal of Banking & Finance*, *37*(11), 4144–4156. https://doi.org/10.1016/j.jbankfin.2013.07.017

Kopecky, K. J., & VanHoose, D. (2004a). Bank capital requirements and the monetary transmission mechanism. *Journal of Macroeconomics*, *26*(3), 443–464. https://doi.org/10.1016/j.jmacro.2003.03.002

Kopecky, K. J., & VanHoose, D. (2004b). A model of the monetary sector with and without binding capital requirements. *Journal of Banking & Finance*, *28*(3), 633–646. https://doi.org/10.1016/S0378-4266(03)00038-4

Li, B. (2022). How does bank equity affect credit creation? Multiplier effects under Basel III regulations. *Economic Analysis and Policy*, *76*, 299–324. https://doi.org/10.1016/j.eap.2022.08.016

Li, B., & Wang, Y. (2020). Money creation within the macroeconomy: An integrated model of banking. *International Review of Financial Analysis*, *71*, Article 101547. https://doi.org/10.1016/j.irfa.2020.101547

Li, B., Xiong, W., Chen, L., & Wang, Y. (2017). The impact of the liquidity coverage ratio on money creation: A stock-flow based dynamic approach. *Economic Modelling*, *67*, 193–202. https://doi.org/10.1016/j.econmod.2016.12.016

Luck, S., & Zimmermann, T. (2020). Employment effects of unconventional monetary policy: Evidence from QE. *Journal of Financial Economics*, *135*(3), 678–703. https://doi.org/10.1016/j.jfineco.2019.07.004

Martin, A., McAndrews, J., Palida, A., & Skeie, D. (2019). Federal reserve tools for managing rates and reserves. *Available at SSRN: https://ssrn.com/abstract=2335506 or http://dx.doi.org/10.2139/ssrn.2335506*.

Martin, A., McAndrews, J., & Skeie, D. (2016). Bank lending in times of large bank reserves. *International Journal of Central Banking*, *12*(4), 193–222.

McLeay, M., Radia, A., & Thomas, R. (2014). Money creation in the modern economy. *Bank of England Quarterly Bulletin*, *Q1*, 14–27.

Modigliani, F., & Miller, M. H. (1958). The cost of capital, corporation finance and the theory of investment. *American Economic Review*, *48*(3), 261–297.

Peek, J., & Rosengren, E. S. (2015). The role of banks in the transmission of monetary policy. In A. N. Berger, P. Molyneux, & J. O. S. Wilson (Eds.), *The Oxford Handbook of Banking* (2 ed., pp. 453–473). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199688500.013.0019

Peydró, J.-L., Polo, A., & Sette, E. (2021). Monetary policy at work: Security and credit application registers evidence. *Journal of Financial Economics*, *140*(3), 789–814. https://doi.org/10.1016/j.jfineco.2021.01.008

Repullo, R., & Suarez, J. (2000). Entrepreneurial moral hazard and bank monitoring: A model of the credit channel. *European Economic Review*, *44*(10), 1931–1950. https://doi.org/10.1016/S0014-2921(99)00069-0

Rezende, M., Styczynski, M.-F., & Vojtech, C. M. (2021). The effects of liquidity regulation on bank demand in monetary policy operations. *Journal of Financial Intermediation*, *46*, Article 100860. https://doi.org/10.1016/j.jfi.2020.100860

Rodnyansky, A., & Darmouni, O. M. (2017). The effects of quantitative easing on bank lending behavior. *The Review of Financial Studies*, *30*(11), 3858–3887. https://doi.org/10.1093/rfs/hhx063

Schularick, M., & Taylor, A. M. (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *American Economic Review*, *102*(2), 1029–1061. https://doi.org/10.1257/aer.102.2.1029

Van den Heuvel, S. (2002). Does bank capital matter for monetary transmission? *Federal Reserve Bank of New York Economic Policy Review*, *8*(1), 259–265.

Van den Heuvel, S. (2007). The bank capital channel of monetary policy. *Working Paper, University of Pennsylvania*.

Vinas, F. (2021). How financial shocks transmit to the real economy? Banking business models and firm size. *Journal of Banking & Finance*, *123*, Article 106009. https://doi.org/10.1016/j.jbankfin.2020.106009

Werner, R. A. (2014a). Can banks individually create money out of nothing?—The theories and the empirical evidence. *International Review of Financial Analysis*, *36*, 1–19. https://doi.org/10.1016/j.irfa.2014.07.015

Werner, R. A. (2014b). How do banks create money, and why can other firms not do the same? An explanation for the coexistence of lending and deposit-taking. *International Review of Financial Analysis*, *36*, 71–77. https://doi.org/10.1016/j.irfa.2014.10.013

Xing, X., Wang, M., Wang, Y., & Stanley, H. E. (2020). Credit creation under multiple banking regulations: The impact of balance sheet diversity on money supply. *Economic Modelling*, *91*, 720–735. https://doi.org/10.1016/j.econmod.2019.09.030

Xiong, W., Li, B., Wang, Y., & Stanley, H. E. (2020). The versatility of money multiplier under Basel III regulations. *Finance Research Letters*, *32*, Article 101167. https://doi.org/10.1016/j.frl.2019.04.024

Xiong, W., & Wang, Y. (2022). A reformulation of the bank lending channel under multiple prudential regulations. *Economic Modelling*, *114*, Article 105916. https://doi.org/10.1016/j.econmod.2022.105916

Table 1. Banks' balance sheet capacities.

Regulation: The subscript R	Balance sheet capacity: BSC_R
CAR	$\frac{E}{car \cdot \gamma_C}$
LR	$\frac{E}{lr} - R - TS$
L-LCR	$\frac{(4 - lcr(\alpha + i_D))(R + TS) + lcr(\alpha + i_D - i_E)E}{lcr(\alpha + i_D)}$
H-LCR	$\frac{(1 - lcr(\alpha + i_D))(R + TS) + lcr(\alpha + i_D - i_E)E}{lcr(\alpha + i_D - \kappa(\mu + i_L))}$
NSFR	$\frac{\beta(R + TS) + (1 - \beta)E}{nsfr \cdot \phi_C - \beta}$

Table 2. Effects of repurchase agreement transactions or discount window lending on banks' balance sheet capacities.

Regulation:	Effect:
The subscript R	$BSC_R^{CB} - BSC_R$
CAR	0
LR	$-\Delta CB$
L-LCR	$-\dfrac{\omega(1+i_{CB})}{\alpha + i_D} \times \Delta CB$
H-LCR	$-\dfrac{\omega(1+i_{CB})}{\alpha + i_D - \kappa(\mu + i_L)} \times \Delta CB$
NSFR	0

Table 3. Effects of interest payments on reserves on banks' balance sheet capacities.

Regulation:	Effect:
The subscript R	$BSC_R^{IPOR} - BSC_R$
CAR	$\frac{1}{car \cdot \gamma_C} \times \Delta E$
LR	$\frac{1}{lr} \times \Delta E - \Delta R$
L-LCR	$\frac{4}{lcr(\alpha + i_D)} \times \Delta R - \frac{i_E}{\alpha + i_D} \times \Delta E$
H-LCR	$\frac{1}{lcr(\alpha + i_D - \kappa(\mu + i_L))} \times \Delta R - \frac{i_E}{\alpha + i_D - \kappa(\mu + i_L)} \times \Delta E$
NSFR	$\frac{\beta}{nsfr \cdot \phi_C - \beta} \times \Delta R + \frac{(1-\beta)}{nsfr \cdot \phi_C - \beta} \times \Delta E$

Note: Changes in equity ΔE and changes in reserves ΔR are equal to interest payments on reserves $i_{IORB}R$.

Table 4. Effects of the central bank's purchase of risky securities on banks' balance sheet capacities.

Regulation:	Effect:
The subscript R	$BSC_R^{PORS} - BSC_R$
CAR	$\frac{\gamma_{RS}}{\gamma_C} \times \Delta RS$
LR	0
L-LCR	$\frac{4hc}{lcr(\alpha + i_D)} \times \Delta RS$
H-LCR	$\frac{hc}{lcr(\alpha + i_D - \kappa(\mu + i_L))} \times \Delta RS$
NSFR	$\frac{nsfr \cdot \phi_{RS}}{nsfr \cdot \phi_C - \beta} \times \Delta RS$

Table 5. Effects of repurchase agreement transactions or discount window lending secured by risky securities on the balance sheet capacities of banks.

Regulation:	Effect:
The subscript R	$BSC_R^{BOEC} - BSC_R$
CAR	0
LR	$-\Delta CB_{RS}$
L-LCR	$\frac{4(\frac{hc-\chi}{1-\chi})}{lcr(\alpha+i_D)} \times \Delta CB_{RS} - \frac{\omega(1+i_{CB})}{\alpha+i_D} \times \Delta CB_{RS}$
H-LCR	$\frac{\frac{hc-\chi}{1-\chi}}{lcr(\alpha+i_D-\kappa(\mu+i_L))} \times \Delta CB_{RS} - \frac{\omega(1+i_{CB})}{\alpha+i_D-\kappa(\mu+i_L)} \times \Delta CB_{RS}$
NSFR	0

Table 6. Differentiating the causes of the positive and negative effects shown in Table 5.

Regulation: The subscript R	Effect: $BSC_R^{BOEC} - BSC_R$
CAR	0
LR	$-\Delta CB_{RS}^{L}$
L-LCR	$\frac{4(\frac{hc-\chi}{1-\chi})}{lcr(\alpha+i_D)} \times \Delta CB_{RS}^{A} - \frac{\omega(1+i_{CB})}{\alpha+i_D} \times \Delta CB_{RS}^{L}$
H-LCR	$\frac{\frac{hc-\chi}{1-\chi}}{lcr(\alpha+i_D-\kappa(\mu+i_L))} \times \Delta CB_{RS}^{A} - \frac{\omega(1+i_{CB})}{\alpha+i_D-\kappa(\mu+i_L)} \times \Delta CB_{RS}^{L}$
NSFR	0

Notes: On the liability side, ΔCB_{RS}^{L} represents increases in repos or discount window borrowings, and ΔCB_{RS}^{A} represents increases in reserves on the asset side. Changes made to the liability side ΔCB_{RS}^{L} give rise to negative effects, whereas asset-side changes ΔCB_{RS}^{A} result in positive effects.

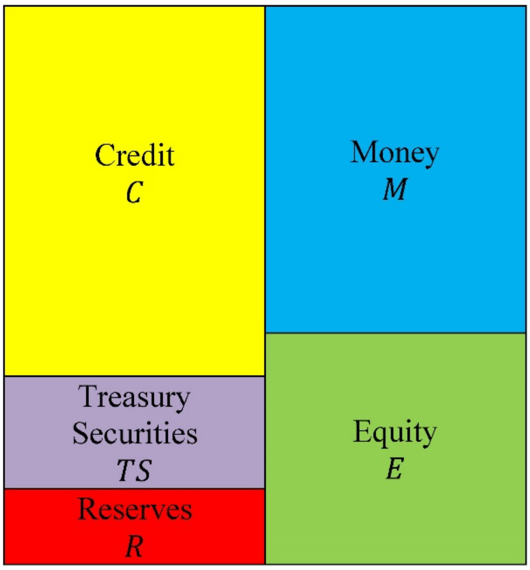

Figure 1. Bank balance sheets.

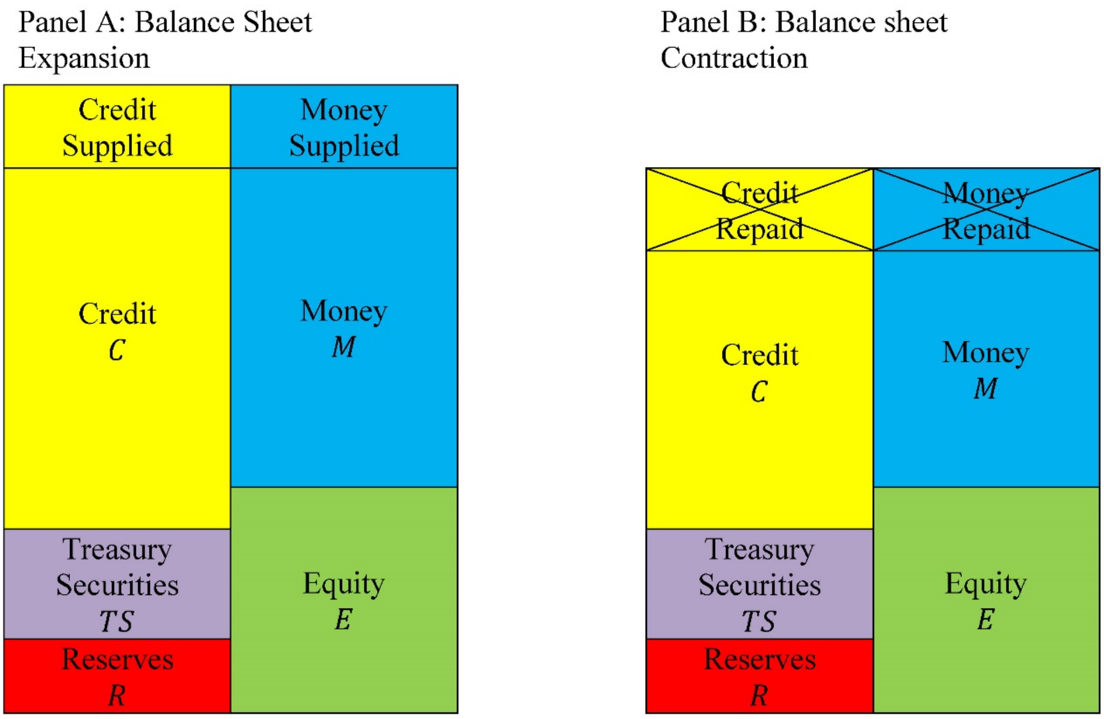

Figure 2. Expansion and contraction of the bank's balance sheet. Panel A shows that the bank is expanding its balance sheet: credit and money are supplied (created). Meanwhile, Panel B depicts that credit and money are repaid (destroyed), causing the bank's balance sheet to shrink.

Panel A

Credit	Money
Treasury Securities TS	
Reserves R	Equity E

$\rightarrow$

Panel B

Credit	Money
Treasury Securities $TS - \Delta TS$	
Reserves $R + \Delta TS$	Equity E

Figure 3. Outright purchases and sales of Treasury securities. Changes in bank balance sheet positions result from an outright purchase or sale of Treasury securities. The purchase (sale) is indicated by $\Delta TS > 0$ ($\Delta TS < 0$).

Panel A

Credit	Money
Treasury Securities TS	
Reserves R	Equity E

$\rightarrow$

Panel B

Credit	Money
Treasury Securities $TS - \Delta CB$	Repos or Discount Window Borrowings ΔCB
Collateral ΔCB	
Reserves $R + \Delta CB$	Equity E

Figure 4. Repurchase agreements and discount window lending. Variations in a bank's balance sheet result from a repo transaction or discount window lending. The repo transaction or lending through the discount window is represented by ΔCB.

Panel A

Credit	Money
Treasury Securities TS	
Reserves R	Equity E

$\rightarrow$

Panel B

Credit	Money
Treasury Securities TS	
Reverse Repos ΔRRP	
Reserves $R - \Delta RRP$	Equity E

Figure 5. Reverse repurchase agreements. Variations in a bank’s balance sheet result from a reverse repo transaction. The reverse repo transaction is denoted by ΔRRP. Meanwhile, banks receive Treasury securities with a value equal to ΔRRP. However, the collateral is on the balance sheet of the central bank.

Panel A

Credit	Money
Treasury Securities TS	
Reserves R	Equity E

$\rightarrow$

Panel B

Credit	Money
Treasury Securities TS	
Term Deposits ΔTD	
Reserves $R - \Delta TD$	Equity E

Figure 6. The term deposit facility. Changes in bank balance sheet positions arise from the operation of a term deposit facility. The term deposit is denoted by ΔTD.

Panel A

Credit	Money
Treasury Securities TS	
Reserves R	Equity E

$\rightarrow$

Panel B

Credit	Money
Treasury Securities TS	
Reserves $R + \Delta R$	Equity $E + \Delta E$

Figure 7. Interest payments on reserves. Changes in bank balance sheet positions arise from an interest payment on reserves. The interest payment on reserves is denoted by $\Delta R = \Delta E = i_{IORB} R$, where i_{IORB} is the interest on reserve balances rate.

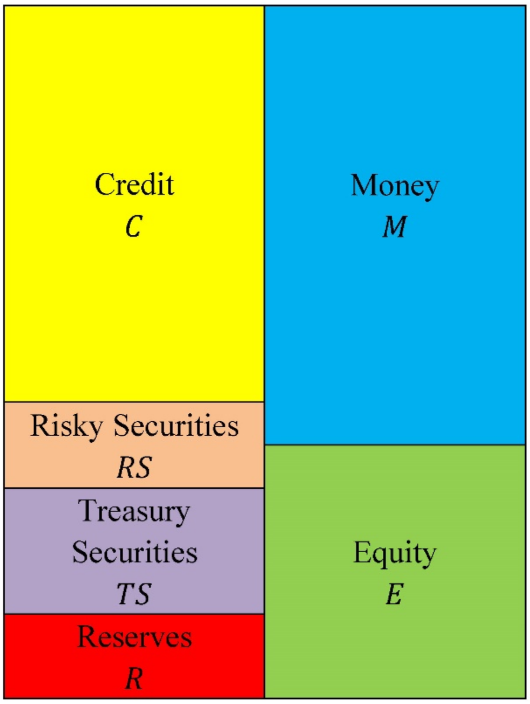

Figure 8. Bank balance sheets with risky securities.

Panel A

Credit	Money
Risky Securities RS	
Treasury Securities TS	
Reserves R	Equity E

$\rightarrow$

Panel B

Credit	Money
Risky Securities $RS - \Delta RS$	
Treasury Securities TS	
Reserves $R + \Delta RS$	Equity E

Figure 9. Purchases of risky securities. Changes in bank balance sheet positions arise from the purchase of risky securities. Purchase is denoted by ΔRS.

Panel A

Credit	Money
Risky Securities RS	
Treasury Securities TS	
Reserves R	Equity E

→

Panel B

Credit	Money
Risky Securities $RS - \frac{\Delta CB_{RS}}{1-\chi}$	
Collateral $\frac{\Delta CB_{RS}}{1-\chi}$	Repos or Discount Window Borrowings ΔCB_{RS}
Treasury Securities TS	
Reserves $R + \Delta CB_{RS}$	Equity E

Figure 10. The use of risky securities as collateral for repurchase agreements and discount window lending. Changes in bank balance sheet positions result from a repo transaction or discount window lending secured by risky securities. The repo transaction or discount window loan is denoted by ΔCB_{RS}. The value of the risky securities that have been pledged is given by $\Delta CB_{RS}/(1-\chi)$, where χ is the collateral haircut established by the central bank.