# The impact of Basel III on money creation: a theoretical analysis

Wanting Xiong, Yougui Wang*

This version: November, 2017

**Abstract**

Recent evidences provoke broad rethinking of the role of banks in money creation. We argue that apart from the reserve requirement, prudential regulations also play important roles in constraining the money supply. Specifically, we study three Basel III regulations and theoretically analyze their standalone and collective impacts. We find that 1) the money multiplier under Basel III is not constant but a decreasing function of the monetary base; 2) the determinants of the bank's money creation capacity are regulation-specific; 3) the effective binding regulation and the corresponding money multiplier vary across different economic states and bank balance sheet conditions.

Keywords: money creation, Basel III, liquidity coverage ratio, capital adequacy ratio, leverage ratio, money multiplier
Journal of Economic Literature Classification: E51, G28, G18, E60

*School of Systems Science, Beijing Normal University, Beijing 100875, P.R. China

# 1 Introduction

Since the crisis struck in September 2008, central banks have greatly expanded the scope of its tools to stimulate the economy by cutting interest rates to the zero lower bound and taking on unconventional measures such as "quantitative easing" (QE). In consequence, there has been commensurate increase in the monetary base together with a tripling or quadrupling of the size of central bank balance sheets. However, these actions have had much less impact on bank lending and the broad money aggregate. In particular, the money multiplier, which used to be reasonably stable in normal times, experienced unprecedented plumbing to less than half of its pre-crisis level (See Figure 1 for the empirical movements of the M0 stock, the M2 stock and the money multiplier in the U.S. [1]).

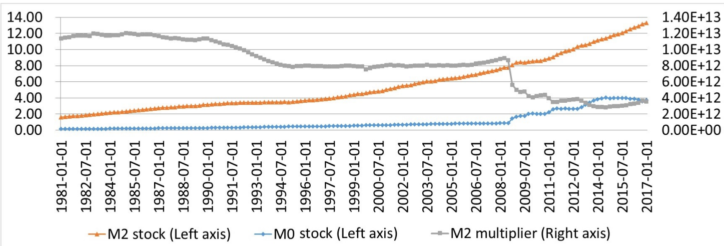


**Figure 1:** The M0 stock (US dollar) , the M2 stock (US dollar) and the money multiplier in the U.S. from 1981-01-01 to 2017-01-31. Data source: https://fred.stlouisfed.org.

Such collapse of the money multiplier and sluggish response of bank lending to expansionary monetary policy stand in stark contrast to the descriptions of the traditional fractional reserve theory of banking (FRT) and the related bank lending channel of monetary transmission. According to the FRT, the lending behavior of an individual commercial bank is constrained by the amount of deposits and the reserve requirement to which it is subject. Since the amount of required reserves is a fraction of the total deposits, the broad money supply by the banking system as whole is a multiplier of the monetary base. This money multiplier is expressed as the inverse of the required reserve ratio in its simplest form and is often considered to be constant. Therefore, a bank lending channel exists wherein monetary shocks to the level of bank reserves are "multiplied up" to greater changes in deposits and deposits, insofar as they constitute the supply of loanable funds, affect bank lending.

The wide gap between the reality and the FRT suggests a serious need to reassess the role of banks in money creation (Werner, 2014; McLeay et al., 2014; Ábel et al., 2016; Botos, 2016). Inherent in the traditional view of banking are two

[1] Relevant discussions and more data illustrations for other countries can be found in Goodhart (2015); Honda (2004); Disyatat (2011).

assumptions: 1) the central bank controls the money supply by varying the supply of reserves and the required reserve ratio, and 2) the availability of reservable deposits is a binding constraint on commercial bank lending. Regarding the first point, it is argued by many (Ryan-Collins et al., 2012; Goodhart, 2010; Komáromi, 2007) that most central banks have shifted their policy target from the quantity control of reserves to the price control of short-term interest rate. In order to achieve the target interest rate and facilitate the smooth functioning of the interbank payment system, reserves are supplied by the central bank non-discretionarily to meet the commercial bank's demand in normal times. Thus, the amount of reserves are mainly determined by the structural characteristics of the payment system. This renders the reserve requirement policy a less important aspect in the central bank governing framework (Bernanke, 2007; McLeay et al., 2014). In fact, several countries, including Canada, Great Britain, Australia, and New Zealand, have no reserve requirement at all. For countries that do retain this policy, it is often exercised with a time lag (e.g. at least 17 days in the U.S.) (Fullwiler, 2012).

Turning to the second point, there are a number of reasons to be skeptical about the causal relationship from reservable deposits to bank lending. For one, with increasingly ease access to non-deposit or nonreservable-deposit fundings, for example, due to the development of wholesale market (Carpenter and Demiralp, 2012), the growth in loan securitization (Loutskina and Strahan, 2009), and the globalization of banking (Puri et al., 2011), it is very much unlikely that banks will cut lending because they cannot replace the shortfall of reservable deposits. More importantly, the implicit assumption that banks are simply a financial intermediary who lends out the deposits saved with them is essentially misplaced. Instead, banks are different from other financial institutions in that they create deposits, which is used as the common method of payments, out of nothing through lending (Moore, 1988; Palley, 1994; Disyatat, 2011; Keen, 2011; McLeay et al., 2014; Werner, 2014). In this sense, loans drive deposits rather than the other way around.

In other words, it can thus be implied that due to recent financial innovation and policy changes, the reserve requirement is playing a less important role in constraining the money creation process. Nevertheless, in contrast to the attenuation of the reserve requirement as a regulatory constraint for commercial banks, prudential regulations become much more stringent and complicated after the recent financial crisis, which renders an non-negligible impact on bank activities (McLeay et al., 2014). Building on the previous rethinkings and criticisms of the FRT, this paper aims to explore why and how prudential regulations could have a constraining effect on the commercial bank's ability to create money, which therefore provides a new insight into the classical money creation process. In particular, we study the influences of the Basel III accord, one of the most influential international framework of prudential regulations proposed by the Basel Committee on Banking Supervision in the hindsight of the 2008 financial crisis (Basel Committee on

Banking Supervision, 2011). Compared to its previous versions, the new Basel accord strengthens the regulatory requirement on the bank's minimum capital position, both by narrowing the definition of eligible capital and by requesting a significant rise of the Capital Adequacy Ratio (CAR). Additionally, the Basel III accord marks the transition of the banking supervision framework to a multi-polar regime, with the additional introduction of new prudential regulations that focus on different financial risks, such as the Liquidity Coverage Ratio (LCR) and the Leverage Ratio (LR) requirement. While the traditional CAR regulation mainly addresses the insolvency risk resulted from loan default or other asset depreciation, the LCR regulation aims to improve banks' liquidity risk profile in stressful times, and the LR regulation tackles with the risks in modeling or estimating the overall risk exposure and serves as a non-discretionary limit on the expansion of bank balance sheet.

Although a profusion of efforts have been made in evaluating and predicting the macroeconomic impact of the Basel III accord, this paper attempts to add to this literature in several aspects. To begin with, we examine the influences of Basel III regulations on the liability side (money) of the commercial bank's balance sheet, so as to complement the more extensive discussions about its effects on the bank's asset side (credit). On the one hand, it is well demonstrated by existing literature that the bank's credit supply will be negatively affected by the tightening of capital related prudential requirement, either in terms of decreased growth rate or increased price, especially in the short term [2].On the other hand, much less attention is paid to the changes in the bank's liability side, i.e. the money supply, as the result of the variations in the regulatory constraints faced by the commercial bank. To the best of our knowledge, a few exceptions can be found in Honda (2004); Panagopoulos (2010); Li et al. (2017). Specifically, Honda (2004) extends the textbook money creation model to incorporate the impact of capital based regulations and demonstrates that the transmission of monetary shocks via the asset (the credit channel) and the commercial bank's liability side (the money channel) are two different mechanisms. Panagopoulos (2010) investigates empirically the influence of Basel II type CAR regulation on Greek banking system and concludes that its money creation process can be favorably explained by the Post Keynesian Structuralism theory of endogenous money. Li et al. (2017) examines the role of the latest LCR regulation in money creation and finds that such regulatory constraint might lead to a reduction in the money multiplier.

Furthermore, we contribute to the understandings about the interactions among different prudential requirements by taking into account the simultaneous imposition of multiple regulatory instruments. While the benefits of such multi-polar

[2] See VanHoose (2007); Peek and Rosengren (2010); Martynova (2015) for reviews of related studies.

regulatory regime in addressing different types of risks and frictions are straightforward, there is considerable uncertainty about the collective consequences of multiple prudential regulations when being imposed at the same time(Haldane, 2015). Therefore, in response to the call of Haldane (2015) for more efforts in examining the complexity of multi-polar regulatory framework, this paper considers three prudential regulations in the Basel III accord, including the CAR, LCR and LR regulations. More specifically, we examine the role of these regulations in the money creation process by answering three questions. The first question is what determines the broad money supply and the corresponding money multiplier when each concerned regulation is taking effect alone. Second, when multiple regulations are imposed at the same time, which of them is the binding constraint that dictates the bank's ability to create money. Last but not least, since most prudential regulations are ratio controls of the items on bank balance sheets, it is also vital to know how the effective binding regulation and the corresponding money multiplier vary with changes in the structure of bank balance sheet in different economic conditions. ~~With the answers to these questions, we will be able to understand why the money multiplier collapses after the massive expansion of the monetary base and advise policy makers on how to boost the banking system's credit creation capacity under multiple prudential regulations in different conditions.~~

In order to answer these questions, we model the money creation process and focus on the behaviors of the commercial bank in a simplified stock-flow consistent framework that respects both the accounting principle and the law of motion between stock and flow variables. To simplify analysis, we assume that the level of bank capital and high quality liquid assets are exogenously given, while the level of loans and deposits are endogenously determined in the money creation process. Also, we abstract from the rest of the economy by assuming that the loan demand is higher than the loan supply and that the interest rate of lending is always profitable for the bank. Compared with works that attempt to assess or predict the more general macroeconomic impact of Basel III in terms of social welfare or aggregate output (e.g. Slovik and Cournède (2011); Allen et al. (2012); Angelini et al. (2015); Miles et al. (2013); Yan et al. (2012); Quinaz and Curto (2016)), we study a shorter logic chain that involves much less intertwined macroeconomic causalities[3] and correspondingly organize our analysis in a paired-down theoretical framework that intends to give qualitative rather than quantitative conclusions about the constraining effects of prudential regulations on money creation. The merits of such approach are that the reasoning process is straightforward and easy to follow, and that the theoretical implications of new Basel regulations in the

[3] For instance, we do not consider the interplay between banks and the rest of the economy, including the impact of the former's credit and money supply on the latter's aggregate demand, as well as the changes in the latter's investment in bank liabilities.

money creation process can be directly compared with those of the classical reserve requirement.

Based on this theoretical framework, we obtain the corresponding expressions for the money supply and money multiplier for each individual regulation, and examine their relations with corresponding determinants. We find that 1) when the banking system is constrained by any of the three prudential regulations, the money multiplier responds negatively to the increase of the monetary base, which is different from the constant money multiplier when the bank is only constrained by the reserve requirement; and 2) rising the monetary base may not boost the broad money supply when the LR regulation acts as the binding constraint; and 3) the determinants of the money supply and the money multiplier are specific to the binding regulation by which the bank is constrained. In the case where multiple regulations take effect simultaneously, we find that the effective binding regulation that casts the most rigid constraint on the bank lending and money creation can be different when there are changes in the underlying economic environment and the bank's balance sheet structure. Consequently, the corresponding money multiplier and its determinants will also vary. We argue that this result calls for special attention from the policy makers because the same policy may have distinct consequences in different scenarios.

The following of the paper is structured as follows. Section 2 elaborates the role of the commercial banks in money creation and the mechanism through which Basel III regulations affect bank lending behaviors and consequently the broad money supply. Section 3 presents the model and the corresponding equilibrium conditions. Section 4 first presents the standalone impact of each individual regulation on money creation in Section 4.1 and further demonstrates the collective influence when all three regulations are simultaneously imposed in Section 4.2. Section 5 draws our conclusions.

## 2 Money creation, commercial bank balance sheet and prudential regulations

> "In the modern economy, most money takes the form of bank deposits. But how those bank deposits are created is often misunderstood: Whenever a bank makes a loan, it simultaneously creates a matching deposit in the borrower's bank account, thereby creating new money."
>
> —McLeay et al. (2014),Bank of England,Quarterly Bulletin 2014 Q1

Commercial banks play a central role in money creation. When a bank makes a loan, the most common way is to directly credit the borrower's deposit account, which thereby expands both sides of the bank's balance sheet. When loans are repaid, the amount of deposits decreases. In this sense, bank lending can never be constrained by the lack of debt financing source because deposits are its own product. Instead, the limit on credit creation comes from the portfolio management of banks to maintain liquid, solvent and profitable, for both voluntary and mandatory reasons. To understand this, let us take a detailed look at the bank's business model and the mechanism through which the reserve requirement and prudential regulations take effect.

The most fundamental way for a bank to profit is to earn the interest spread between its assets (e.g. loans) and liabilities (e.g. deposits), which gives the bank a natural motivation to make more loans and expand the balance sheet. On the other hand, such business model also entails the bank's taking on various risks, which is rooted in the asymmetric properties of its assets and liabilities. Deposits should be paid on demand while loans become due only on specific dates, thereby the bank faces potential maturity mismatch that leads to liquidity risk. Also, banks face solvency risk when loans get defaulted or massive asset depreciation happens in economic downturns. Usually, the liquidity risk is managed by banks through a buffer of liquid assets and the access to stable funding sources during stressed market conditions, while the solvency risk is coped with by holding sufficient amount of capital and careful risk management of their assets (see Fig. 2 for illustration).

From this perspective, one function of the reserve requirement is to serve as a liquidity regulation that guarantees banks' holding of enough liquid reserves rather than illiquid loans to meet their payment needs because of deposit withdrawal or transfer. However, with the central bank's policy target shifted to short-term interest rate, the commercial bank's increasing access to funds that bears no reserve constraint and the facilitation of a well-functioning interbank market for reserves, this constraint has ceased to be an influential concern when banks make loans.

In addition, driven by the desire for profit, banks are often prone to underestimate the liquidity and solvency risks which gradually build up during economic booms when the expectations for profitability are collectively good and the short-term fundings are stable and easy to obtain. Also, the explicit or implicit government guarantees in stressed conditions including deposit insurance, bailing-out and last-resort lending, also give rise to the problem of "moral hazard" whereby banks take on excessive risks and maintain lower levels of capital and liquid assets they would otherwise. This sort of development is argued to be the reason for the expansion of bank lending and the deterioration of financial stability in the lead up to the financial crisis (McLeay et al., 2014; Farag et al., 2013; Fullwiler, 2012).

Therefore, in order to guard against this intrinsic destabilizing nature of the financial sector, prudential regulations are indispensable in constraining bank behaviors in a more targeted fashion (Horváth et al., 2014; Jakab and Kumhof,

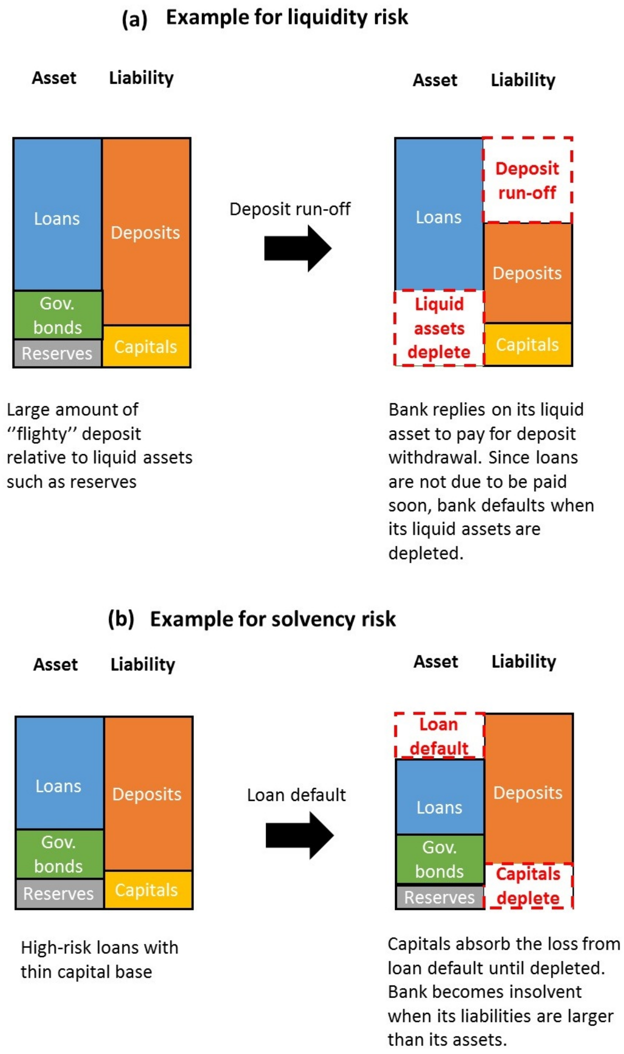


**Figure 2:** Illustration for liquidity risk (a) and solvency risk (b). Figure adapted from Farag et al. (2013).

2015; Li et al., 2017; Farag et al., 2013; Dermine, 2013). Consequently, since the introduction of capital requirements in the Basel I accord, the impact of bank capital and capital regulations on bank lending has been a heated topic for researchers. In the aspect of theory, several mechanisms are proposed to explain how bank capital and capital requirement affect bank lending: 1) the threshold effect of binding capital constraint, where capital-constrained banks become more responsive to contractionary monetary policy and less motivated by expansionary policy (Van den Heuvel, 2002b; Furfine, 2001; Honda, 2004); 2) the bank profit effect, where monetary policy tightening results in reduced bank profit that constitutes lower bank equity and thus leads to a persistent decline in bank lending (Van den Heuvel, 2002a; Chami and Cosimano, 2010); 3) the risk premium effect, where the level of bank capital acts as the signal of the bank's health for its creditors and thereby affects the bank's risk premium in raising external funds (Disyatat, 2011). As for empirical evidences, the important roles of bank capital and capital regulations in bank lending have been generally confirmed. On the one hand, it is well documented by researches across different countries and time periods[4] that individual banks' capital position is an important factor in determining their response to monetary shocks. On the other hand, more recent works (Francis and Osborne, 2009, 2012; Bridges et al., 2014; Aiyar et al., 2016; Mésonnier and Monks, 2014; Noss and Toffano, 2014) focus on the impact of varying capital requirement and estimate a short-term reduction of bank lending ranging from 1.2% to 4.5% due to a 1% increase in capital requirement.

Notwithstanding the extensive discussions on the impact of capital requirement on the bank lending channel, few investigations have been made regarding the constraining effect of other prudential regulations on the money creation process such as the newly proposed LCR regulation, not to mention the more complicated case where multiple prudential regulations are simultaneously imposed[5].

In the Basel III accord framework, the liquidity risk is addressed by the LCR regulation while the solvency risk is attended by the CAR and LR regulations. Next, we will explain the meanings of these regulations and how they limit bank lending and the money supply.

**Liquidity Coverage Ratio** Basel III accord requires a bank to hold sufficient high-quality liquid assets ($HQLA$) to cover its total net cash outflow ($NCOF$) over 30 days in stressed conditions. Mathematically, the liquidity coverage ratio is defined as

$$LCR = \frac{HQLA}{NCOF}. \tag{1}$$

The minimum liquidity coverage ratio was initially set to be 60% in 2015 and should rise in equal annual steps to reach 100% on 1 January 2019.

According to the Basel III regulations, high quality liquid assets are assets that have low default risk and easy and immediate convertibility into cash at little or no loss of value. Meanwhile, the total net cash outflows is defined as the total

[4] For the U.S., see Peek and Rosengren (1995a,b); Kishan and Opiela (2000, 2006); for EU countries, see Gambacorta and Mistrulli (2004); Altunbaş et al. (2002); Gambacorta and Marques-Ibanez (2011); Puri et al. (2011); for India, see Nachane et al. (2006); Albertazzi and Marchetti (2010); for Japan, see Peek and Rosengren (1997); for Spain, see Jiménez and Ongena (2012); for Malaysia, see Abdul Karim et al. (2011).

[5] See Li et al. (2017); Xiong et al. (2017) for exception.

expected cash outflows ($OF$) minus the total expected cash inflows ($IF$) up to an aggregate cap of 75% of the total expected cash outflows in the specified stress scenario for the subsequent 30 calendar days, i.e.

$$NCOF = OF - min\{IF, 0.75OF\}. \tag{2}$$

The 75% cap of total expected cash outflows is introduced to prevent banks from relying solely on anticipated inflows to meet their liquidity requirement so that they must maintain a minimum amount of stock of $HQLA$ equal to 25% of the total cash outflows(Basel Committee on Banking Supervision, 2013).

**Risk-based capital adequacy ratio** To strength the capital framework of the banking sector, the Basel III accord raises the minimum requirement of bank capital in relation to the risk-weighted assets ($RWA$) and introduces two additional capital buffers: a mandatory “capital conservation buffer” and a “discretionary counter-cyclical buffer”, allowing national regulators to require additional capital buffer during periods of high credit growth. The risk-based capital adequacy ratio is usually defined based on the Tier-1 core capital ($CET1$), which is bank capital with the highest quality classification, over the risk-weighted assets, i.e.

$$CAR = \frac{CET1}{RWA}. \tag{3}$$

Compared to Basel II, the minimum requirement of $CET1$ over $RWA$ is raised from 2% to 4.5%, while the mandatory “capital conservation buffer” requires 2.5% and the “discretionary counter-cyclical buffer” ranges from 0% to 2.5%. Therefore, the actual minimum requirement of $CAR$ facing by banks is 7% in all periods and even up to 9.5% in certain conditions.

**Leverage Ratio** The leverage ratio regulation is a non-risk-based capital requirement. It is calculated by dividing the amount of Tier 1 capital by the bank’s average total consolidated assets($TA$), which includes the exposures of all assets and non-balance sheet items. In other words, the leverage ratio is defined as

$$LR = \frac{CET1}{TA}. \tag{4}$$

The leverage ratio is introduced as a backstop to the risk-based capital adequacy ratio with the aim of constraining excess leverage in the banking system and providing an extra layer of protection against model risk and measurement error. Basel III requires the banks to maintain a leverage ratio in excess of 3%. A higher minimum leverage ratio is requested by the U.S. Federal Reserve for 8 Systemically important financial institution (SIFI) banks and their insured bank holding companies. It is argued by some that the simple leverage ratio is a much more reliable guide and predictor of actual bank default than the risk-based ratio (Alessandri and Haldane, 2011; Blundell-Wignall and Roulet, 2013).

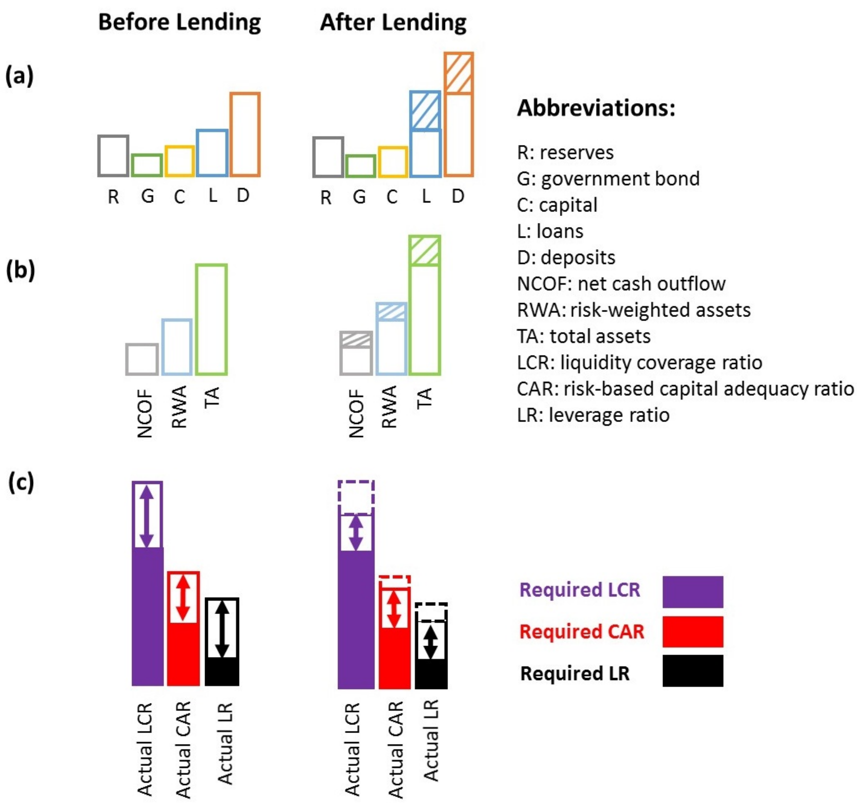


**Figure 3:** Changes in the components of bank balance sheet and monitor instruments under Basel III regulations after increasing the loan stock. (a) After making new loans in excess of due loan repayments, the stocks of loans and deposits increase while the stocks of reserves, government bonds and bank capital remain unchanged. (b) Along with the increase of the loan stock, banks are exposed to higher liquidity and solvency risks. As a result, the net cash outflow, risk-weighted assets and total assets rise accordingly. However, the amount of high quality liquid assets (including reserves and zero-risk-weight government bonds) and bank capital, which serve as the credit base for banks to guard against liquidity and solvency risks, do not change. (c) Because of the increasing denominators and the constant nominators, the actual liquidity coverage ratio, risk-based capital adequacy ratio and the leverage ratio drop and approach to their corresponding minimum requirements set by the Basel III regulations. Therefore, given no improvement of the bank's credit base, the implementation of prudential regulations casts a maximum limit for the amount of loans and deposits that can be created by the bank.

In essence, the Basel III accord sets a minimum limit on the banks' holdings of high liquid assets and core capital, which serve as the credit base to guard against the liquidity and solvency risks for banks to conduct the business of borrowing short and lending long. However, it is often difficult for banks to improve their credit base in the short-term or without the help of external forces. While individual banks can adjust their holdings of the stock of high liquid assets, the available stock of high liquid asset for the banking system as a whole is fundamentally dependent on central bank policies. For the capital stock to grow, a bank has to issue additional common shares or accumulate retained earnings, which will impair the bank's profitability performance in terms of reduced return to equity or lower dividend payout ratio. Therefore, given the current level of the credit base, the credit creation ability of banks is constrained by the prudential regulations. Specifically, as illustrated in Fig. 3(a), when the lending flow exceeds the repayment flow, the stock of loans and deposits simultaneously increase. As a result, the amount of total assets rises. Meanwhile, the increase of the loan stock is accompanied by rising exposure to default risk, which results in higher quantity of risk-weighted assets. Similarly, higher liquidity risk comes with the increase of the deposit stock or other liabilities, which brings about larger expected net cash outflow. On the other hand, the amount of bank capital and that of high quality liquid assets such as reserves and government bonds with zero risk-weight are not directly affected by the behaviors of bank lending and loan repayment. In other words, compared to the fast easy expansion of the stocks of loans and deposits, changes in the banking system's liquidity and equity positions are much slower and more dependent on external forces. In consequence, as shown in Fig. 3(c), the actual liquidity coverage ratio, risk-based capital adequacy ratio and leverage ratio usually decrease along with the increase of loans and deposits. When these ratios reach or come close to the Basel III's minimum requirements, banks will be more cautious or stop the expansion of loans due to the high cost of breaching the regulation[6]. In other words, if there is no regulation, there is no theoretical limit for the credit supply of banks before massive defaults or funding flights kick in. But if given the minimum requirement of concerned prudential regulation and the current level of the bank's credit base and the risk conditions of its asset and liability, we can derive at a maximum limit for the loans and deposits that can be created by the bank.

## 3 The model

To demonstrate the impacts of Basel III regulations on the credit creation process, we employ a stock-flow consistent dynamical model modified based on the work of Li et al. (2017)[7]. We consider a representative commercial bank with a simplified

[6] In order to increase the actual LCR,CAR and LR, banks may also increase the share of safe or short-term loans and raising more stable funds. However, the effects of these actions are marginal compared with the overall quantity control of loans and deposits.

[7] Compared with the model in Li et al. (2017), we make a more realistic assumption about the commercial bank's balance sheet structure by considering bank capital and government bonds in

balance sheet shown in Table. 1. On the asset side, there are three items: reserves ($R$), government bonds with zero risk-weight ($B$) and loans ($L$) with an average risk-weight of $\gamma$. On the liability side, we only consider deposits ($D$) and bank capital ($C$). Following Krug et al. (2015), we do not make distinction between core capital Tier 1 and other capital.

To focus our analyses on the impacts of prudential regulations on commercial bank behaviors, we assume that the demand for loans is always larger than the supply of loans and that the interest rate is constant and profitable for the bank. In addition, due to the reasons mentioned in the last section, we suppose there is no change in bank's liquidity and equity positions in the short-run, i.e. the stocks of reserves, government bonds and bank capital are constant and exogenously given. Also, banks are assumed to hold no voluntary buffer above the minimum capital or liquidity requirements. With these assumptions, we abstract from the real economy, loan demand and the price effect of varying interest rate while keeping only the minimum elements necessary in the study of the constraining effect of Basel III on money creation. These simplifications allow us to focus on the complexity of the multi-polar prudential regulation framework itself, which includes the difference in the standalone impact of individual policy instrument and their complicated interactions when simultaneously imposed. Moreover, the adopted stock-flow consistent framework guarantees the consistency of our analyses with both the accounting principle and the law of stock-flow motion. These properties make it easier to integrate our findings in more complicated stock-flow consistent models such as the inspiring work of Caiani et al. (2016) where the banking sector is considered to be special and not deduced to a mere financial intermediary.

**Table 1:** A simplified balance sheet for a representative commercial bank

| Asset | Liability |
|---|---|
| Reserves ($R$) | Deposits ($D$) |
| Government bonds ($G$) | |
| Loans ($L$) | Capital($C$) |

Suppose time is discrete and the unit of each time step is one month. Due to the accounting consistency, the following identity between assets and liabilities should always hold:

$$R(t) + G(t) + L(t) = D(t) + C(t). \tag{5}$$

addition to reserves, deposits and loans. Such extension allows us to explore the constraining effects of different prudential regulation including the LCR, CAR and LR regulations.

The stocks of reserves, government bonds and bank capital are assumed to be always positive and exogenously given. In other words,

$$R(t) = R, \tag{6}$$

$$G(t) = G, \tag{7}$$

$$C(t) = C. \tag{8}$$

At each time $t$, changes in the stock of loans and deposits are both governed by the difference between the new bank lending flow ($LF$) and the loan repayment flow ($RP$)[8], i.e.

$$L(t+1) - L(t) = LF(t) - RP(t), \tag{9}$$

$$D(t+1) - D(t) = LF(t) - RP(t). \tag{10}$$

For the initial period, we assume there is no loans ($L(1) = 0$) and $D(1) = L(1) + R(1) + G(1) - C(1) = R + G - C$. Because the amount of deposits cannot be negative, $R + G - C \geq 0$ must hold.

For simplicity, we also assume all loans are amortized with an average maturity of $\theta$. In other words, a new loan made at month $t'$, $LF(t')$, will be paid off at month $t' + \theta$. Thus the amount of repayment for this loan due at month $t$, denoted as $RP_{t'}(t)$, is

$$RP_{t'}(t) = \begin{cases} 0, t \neq t'+1, t'+2, \ldots, t'+\theta; \\ \frac{LF(t')}{\theta}, t = t'+1, t'+2, \ldots, t'+\theta. \end{cases} \tag{11}$$

Thus, the total repayment flow due at time $t$, $RP(t)$, can be computed as the sum of repayments due for all loans made in the past $\theta$ periods, which is given by

$$RP(t) = \begin{cases} 0, t = 1 \\ \sum_{t'=1}^{t-1} \frac{LF(t')}{\theta}, 1 < t < \theta; \\ \sum_{t'=t-\theta}^{t-1} \frac{LF(t')}{\theta}, t \geq \theta. \end{cases} \tag{12}$$

[8] In addition to bank lending and loan repayment, the stock of deposits will also be changed by the flows of cash deposits and withdrawal. For simplicity we assumes no cash and focus on the behaviors of lending and repayment.

As articulated in Section 2, the bank's decision of making new loans is constrained by prudential regulations because the credit base cannot be increased in the short term. Let us denote $L_{max}$ as the maximum loan stock for the bank to satisfy the minimum requirement of concerned prudential regulation given the current level of credit base and exposures to risk. Because we do not consider the bank's voluntary holding of additional credit base, the increment of the outstanding loan stock $L(t)$ should be no more than its difference with the maximum loan stock $L_{max}$, i.e.

$$L(t+1) - L(t) = LF(t) - RP(t) = \rho(L_{max} - L(t)), \tag{13}$$

where $\rho$ ($\rho \in [0,1]$) controls the speed at which $L(t)$ approaches to $L_{max}$. From Equation 13, we can obtain the expression for the new lending flow as

$$LF(t) = RP(t) + \rho(L_{max} - L(t)). \tag{14}$$

When the dynamical model reaches the stock-flow equilibrium, all stocks and flows should be constant. Thus, supposing the system reaches equilibrium at time $t^*$, we should have $\forall t \geq t^*$,

$$L(t) = L^*, \tag{15}$$

$$D(t) = D^*, \tag{16}$$

$$LF(t) = RP(t) = LF^* = RP^*, \tag{17}$$

where $L^*$, $D^*$, $LF^*$ and $RP^*$ are respectively the equilibrium values of loans, deposits, the flow of new lending and the flow of repayment. Also, from Equations 14 and 17, we find that the equilibrium loan stock is at the maximum value permitted by the concerned prudential regulation, i.e.

$$L^* = L_{max}. \tag{18}$$

In addition, by manipulating Equations 9,12, 15 and 17 (details are shown in A), we can prove that

$$LF^* = RP^* = \frac{2}{1+\theta} L^*,\ t \geq t^*. \tag{19}$$

We assume there is no cash in our model, thus the monetary base $MB$ is then equal to the amount of reserves, and the broad money supply $M$ is hereafter the amount of deposits. Combining Equations 5,18, the broad money supply can be rewritten as a function of the maximum loan stock under the concerned prudential regulation as follows:[9]

$$M = R + G - C + L_{max}. \quad (20)$$

Correspondingly, based on Eqs. 6,7 and 8, the money multiplier $m$, defined as the ratio of the broad money supply and monetary base, is then given by

$$m = \frac{M}{MB} = 1 + \frac{G}{R} - \frac{C}{R} + \frac{L_{max}}{R}. \quad (21)$$

Henceforth, based on this model, we move on to examine the specific impacts of Basel III regulations on money creation.

# 4 Impacts of Basel III regulations

In this section, we will first analyze in Sec.4.1 the standalone effect of individual regulation on credit creation by deriving at the maximum limit on bank loans when only one regulatory instrument is imposed and solving for the corresponding equilibrium money supply and money multiplier. We will also briefly analyze the determinants of the money supply and the money multiplier in each condition. Then in Sec.4.2, we will inspect the collective impact of the simultaneous imposition of all policy instruments, identify which of them is the binding constraint and analyze how the corresponding money multiplier changes across different economic states and with varying bank balance sheet condition.

## 4.1 Standalone impact of individual regulations

**The liquidity coverage ratio** Assume the minimum requirement of LCR is $r_{LCR}$. The constraint in Equation 1 can be rewritten as

$$r_{LCR} * NCOF \leq HQLA. \quad (22)$$

Since only reserves and government bonds with zero risk-weight are qualified as high quality liquid assets in our model, we have

$$HQLA = R + G. \quad (23)$$

[9] Note that because we do not consider banks' voluntary holdings of excessive reserves and bank equities above the minimum prudential requirement, these expressions reflect the banking system's maximum ability to create money. Since our purpose is to evaluate the policy impact of the Basel III regulation on money creation rather than estimating the real values of the money supply and the money multiplier, we will focus on the relative changes of these values when the regulation of concern is different or when the economic condition varies.

As indicated in Equation 2, the net cash outflow is a function of the expected cash outflow and inflow within 30 days. In real world, the total expected cash outflows are calculated by multiplying the outstanding balances of various categories or types of liabilities and off-balance sheet commitments by the rates at which they are expected to run off or be drawn down, while the total expected cash inflows are calculated by multiplying the outstanding balances of various categories of contractual receivables by the rates at which they are expected to flow in. In our model, we assume the total cash outflow ($OF$) comes from the potential loss of deposits, which is given by

$$OF(t) = \mu D(t), \tag{24}$$

where $\mu$ is the run-off ratio of deposit loss to total deposits. The total cash inflow ($IF$) is supposed to be constituted by the expected loan repayment due in one month with a discount rate of 50%[10] due to the assumption of stressed condition, i.e.

$$IF(t) = 0.5RP(t). \tag{25}$$

According to the definition of net cash outflow in the LCR regulation (Equation 2), when the total expected inflow is not less than 75% of the total expected outflow, we have $NCOF(t) = OF(t) - 0.75OF(t) = 0.25OF(t)$; otherwise, the net cash outflow is the difference of outflow and inflow, that is, $NCOF(t) = OF(t) - IF(t)$. Putting these two conditions together with Equations 24 and 25, the following expression for the net cash outflow can be obtained:

$$NCOF(t) = \begin{cases} 0.25\mu D(t), IF(t) \geq 0.75OF(t); \\ \mu D(t) - 0.5RP(t), IF(t) < 0.75OF(t). \end{cases} \tag{26}$$

Next, let us consider the first condition, $IF(t) \geq 0.75OF(t)$, where the LCR regulation is equivalent to the following constraint:

$$0.25\mu r_{LCR} D(t) \leq R + G. \tag{27}$$

[10] According to the official document regarding the LCR regulation provided by the Basel committee(Basel Committee on Banking Supervision, 2013), different inflow rate are set by the Basel III accord for different types of bank assets. For instance, the accord requires that a bank should assume that maturing reverse repurchase or securities borrowing agreement secured by Level 1 assets (which corresponds to overnment bonds and bank reserves in our model) will be rolled-over and will not give rise to any cash inflows (0%). On the other hand, the inflow rate for non-HQLA assets varies from 0%-100% for different types of counterparties based on their abilities to fulfill debt obligations in stressed conditions. Here we take 50% as an exemplary inflow discount rate for the repayments received from outstanding bank loans. Discussions for relaxing this assumption are given in Appendix C.

Due to the accounting consistency in Equation 5, we can rewrite the above inequality as a function of $L(t)$:

$$0.25\mu r_{LCR}\left[R+G-C+L(t)\right] \leq R+G, \tag{28}$$

When Equation 28 takes equality, the bank's actual capital adequacy ratio reaches the minimum policy requirement and the loan stock achieves its maximum value, i.e. $L(t) = L_{max}$. With simple manipulations, it is easy to obtain that

$$L_{max} = (\frac{4}{\mu r_{LCR}} - 1)(R+G) + C. \tag{29}$$

Substituting Equation 29 into Equations 20 and 21, we have the equilibrium expressions for the broad money supply and money multiplier respectively as

$$M = \frac{4(R+G)}{\mu r_{LCR}}, \tag{30}$$

$$m = \frac{4}{\mu r_{LCR}}(1+\frac{G}{R}). \tag{31}$$

In order to examine the response of the bank's money creation capacity when there is a shock to the level of the monetary base under the constraint of the LCR regulation, ceteris paribus, we can take the partial derivatives of Equations 30 and 31 with respect to the level of bank reserves, the results of which are given as follows:

$$\frac{\partial M}{\partial R} = \frac{4}{\mu r_{LCR}} > 0, \tag{32}$$

$$\frac{\partial m}{\partial R} = -\frac{4G}{\mu r_{LCR} R^2} < 0. \tag{33}$$

In other words, in this situation, when the central bank raises the monetary base, the broad money supply will also increase, but not by a constant money multiplier as in the case where the bank is constrained by the reserve requirement. Instead, the money multiplier falls with the increase of reserves.

Similarly, it can be inferred from Equation 30 that $\frac{\partial M}{\partial G} > 0$, which demonstrates the positive dependence of the money supply on the amount of government bonds with zero-risk weight. In addition, we find that both the the money supply and the money multiplier are negatively dependent on the minimum policy ratio $r_{LCR}$ and on the deposit run-off ratio $\mu$ ($\frac{\partial M}{\partial r_{LCR}} < 0$, $\frac{\partial m}{\partial r_{LCR}} < 0$, $\frac{\partial M}{\partial \mu} < 0$, $\frac{\partial m}{\partial \mu} < 0$).

In the second condition where $IF(t) < 0.75OF(t)$, considering Equations 23 and 26, the LCR regulation in Equation 22 takes the following form:

$$r_{LCR}[\mu D(t) - 0.5RP(t)] \leq R + G. \tag{34}$$

Similarly, when $L(t) = L_{max}$, the above inequality takes equality. Based on Equations 17,19 and 18, we know that $\forall t \geq t^*, RP(t) = \frac{2}{1+\theta}L_{max}$. Also, from Equation 5,16 and 18, we can have $\forall t \geq t^*, D(t) = R + G - C - L_{max}$. By substituting the expressions of $RP(t)$ and $D(t)$ in terms of $L_{max}$ into Equation 34 with a few manipulations, we can obtain the expression for the maximum loan stock as follows:

$$L_{max} = \frac{(1+\theta)\left[(R+G)(1-\mu r_{LCR}) + \mu r_{LCR} C\right]}{r_{LCR}[\mu(1+\theta) - 1]}. \tag{35}$$

As a result, the equilibrium money supply and money multiplier are respectively given by

$$M = \frac{(R+G)(1+\theta - r_{LCR}) + r_{LCR}C}{r_{LCR}[\mu(1+\theta) - 1]}, \tag{36}$$

$$m = \frac{(1+\frac{G}{R})(1+\theta - r_{LCR}) + r_{LCR}\frac{C}{R}}{r_{LCR}[\mu(1+\theta) - 1]} \tag{37}$$

Correspondingly,

$$\frac{\partial M}{\partial R} = \frac{1+\theta - r_{LCR}}{r_{LCR}[\mu(1+\theta) - 1]} > 0, \tag{38}$$

$$\frac{\partial m}{\partial R} = -\frac{(1+\theta - r_{LCR})G + r_{LCR}C}{r_{LCR}[\mu(1+\theta) - 1]R^2} < 0, \tag{39}$$

which indicates that after a positive shock to the monetary base, the broad money supply will increase, but the size of the increment decreases with the scale of reserves. Again the money multiplier is not a constant as in the case where the banking system is only regulated by the reserve requirement. In addition, both the money supply and money multiplier respond negatively to the increase of the minimum requirement of LCR ($\frac{\partial M}{\partial r_{LCR}} < 0, \frac{\partial m}{\partial r_{LCR}} < 0$ ).

Furthermore, we find that the money supply is not only a increasing function of the bank's holdings of government bonds ($\frac{\partial M}{\partial G} > 0$), but also the amount of capital ($\frac{\partial M}{\partial C} > 0$). Like reserves, government bonds are high quality liquid assets that contribute to the bank's resilience against maturity mismatch. Bank capital, on the other hand, serve as the non-debt financing source that is not exposed to liquidity risk and as the signal of the bank's health for its creditors. Therefore, other things equal, well capitalized banks are able to have more expected cash inflow and less outflow in a liquidity stressed condition than low-capital banks. In other words, the banking system's ability to create money is higher when it holds more capital.

Apart from the amount of high quality liquid assets and bank capital, we can see from $\frac{\partial M}{\partial \mu} < 0, \frac{\partial M}{\partial \theta} < 0, \frac{\partial m}{\partial \mu} < 0, \frac{\partial m}{\partial \theta} < 0$ that the reduction of the bank's exposure to liquidity risk, either due to more stable debt financing source or the shortening of the average maturity of loans, will also lead to increases in both the money supply and the money multiplier.

Because the expressions for the expected cash inflow and $IF^*$ and $OF^*$ in the equilibrium are respectively

$$IF^* = 0.5RP^* = \frac{L^*}{1+\theta}, \tag{40}$$

$$OF^* = \mu D^*, \tag{41}$$

we can rewrite the conditions of $IF^* \geq 0.75OF^*$ and $IF^* < 0.75OF^*$ as a function of $\mu, \theta, R, G, C$ following the manipulations shown in B. In specific, the two conditions are respectively equivalent to $\mu \leq \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}$ and $\mu > \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}$.

In summary, the full expressions for the equilibrium money supply and money multiplier are respectively given by

$$M_{LCR} = \begin{cases} \frac{4(R+G)}{\mu r_{LCR}}, & \mu \leq \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}; \\ \frac{(R+G)(1+\theta-r_{LCR})+r_{LCR}C}{r_{LCR}[\mu(1+\theta)-1]}, & \mu > \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}, \end{cases} \tag{42}$$

$$m_{LCR} = \begin{cases} \frac{4(1+\frac{G}{R})}{\mu r_{LCR}}, & \mu \leq \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}; \\ \frac{(1+\frac{G}{R})(1+\theta-r_{LCR})+r_{LCR}\frac{C}{R}}{r_{LCR}[\mu(1+\theta)-1]}, & \mu > \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}. \end{cases} \tag{43}$$

**The risk-based capital adequacy ratio** For simplicity, our model does not distinguish the quality of bank capital and assumes all capital are qualified in the calculation of the risk-based capital adequacy ratio. Denoting $r_{CAR}$ as the minimum policy requirement, we can have the following expression for the CAR regulation:

$$C(t) \geq r_{CAR} * RWA(t), \tag{44}$$

where $C(t) = C$ and the amount of risk-weighted assets $RWA$ is computed as the product of bank assets and their corresponding risk-weight, as given by

$$RWA(t) = 0 * (R+G) + \gamma L(t) = \gamma L(t). \tag{45}$$

When Equation 44 takes equality, the banking system reaches its maximum credit creation ability, which yields

$$L_{max} = \frac{C}{\gamma r_{CAR}}. \tag{46}$$

Substituting Equation 46 into Equations 20 and 21, we have the equilibrium expressions for the money supply and the money multiplier as follows:

$$M_{CAR} = R + G + (\frac{1}{\gamma r_{CAR}} - 1)C. \tag{47}$$

$$m_{CAR} = 1 + \frac{G}{R} + (\frac{1}{\gamma r_{CAR}} - 1)\frac{C}{R} \tag{48}$$

Furthermore, it can be demonstrated that

$$\frac{\partial M_{CAR}}{\partial R} = 1 > 0, \tag{49}$$

$$\frac{\partial m_{CAR}}{\partial R} = -\frac{G + (\frac{1}{\gamma r_{CAR}} - 1)C}{R^2} < 0. \tag{50}$$

Similar as in the case of LCR regulation, the broad money supply is an increasing function of the monetary base whereas the money multiplier is a decreasing function of the monetary base. As indicated by $\frac{\partial M_{CAR}}{\partial R} = 1$, the increase of reserves will not have any multiplier effect on the broad money supply.

In addition, the broad money supply is positively dependent on the amount of government bonds and bank capital ($\frac{\partial M}{\partial G} > 0$, $\frac{\partial M}{\partial C} > 0$). Moreover, we can see that the values of money supply and money multiplier also depend on the average default risk of bank loans ($\gamma$) and the minium policy requirement of CAR ($r_{CAR}$) in that $\frac{\partial M}{\partial \gamma} < 0$, $\frac{\partial m}{\partial \gamma} < 0$, $\frac{\partial M}{\partial r_{CAR}} < 0$, $\frac{\partial m}{\partial r_{CAR}} < 0$.

**The leverage ratio** With the minimum requirement of leverage ratio being $r_{LR}$, the bank faces the following constraint:

$$C(t) \geq r_{LR} * TA(t), \tag{51}$$

where $C(t) = C$ and $TA(t) = R + G + L(t) = D(t) + C$. When the equality is taken, the loan stock reaches its maximum limit, which is given by

$$L_{max} = \frac{C}{r_{LR}} - R - G. \tag{52}$$

Correspondingly, the equilibrium money supply and money multiplier are

$$M_{LR} = (\frac{1}{r_{LR}} - 1)C, \tag{53}$$

$$m_{LR} = (\frac{1}{r_{LR}} - 1)\frac{C}{R} \tag{54}$$

The responses of money supply and money multiplier to reserve shocks are respectively given by

$$\frac{\partial M_{LR}}{\partial R} = 0, \tag{55}$$

$$\frac{\partial m_{LR}}{\partial R} = -(\frac{1}{r_{LR}} - 1)\frac{C}{R^2} < 0. \tag{56}$$

As shown by Equation 53, the determinants of the broad money supply only include the minimum policy requirement of LR and the amount of bank capital. Thus, the only way to increase the money supply under the given LR regulation is to increase the amount of bank capital ($\frac{\partial M_{LR}}{\partial C} > 0$). In other words, rising the monetary base will have no impact on the banking system's broad money supply and the only consequence of this action is the reduction of the money multiplier.

Heretofore, we have examined the standalone impact of each individual regulation on the bank's ability to lend and create money. To conclude, we summarize these results in Table 2. We find that 1) the tightening of both the prudential requirements and the reserve requirement will have a negative impact on the banking system's ability to create money; and 2) in contrast to the constant money multiplier based on the reserve requirement, the money multiplier under the Basel III accord is a decreasing function of the monetary base and the broad money supply may or may not expand when there is a positive shock to the monetary base; and 3) due to the different constraining effects of different regulations to which the bank is subject, the money creation process are sensitive to different types of economic changes. For instance, the variation of the level of bank capitals can affect the money supply and the money multiplier only when the banking system is constrained by capital-based requirements of the CAR and the LR regulations. On the other hand, the stability of the bank's debt-based financing source and the maturity structure of loans only matter when the LCR regulation is taking effect.

**Table 2:** Comparison of the standalone impact of Basel III regulations with the reserve requirement on money creation

| | Reserve requirement | LCR regulation | CAR regulation | LR regulation |
|---|---|---|---|---|
| Purpose | monetary control and prudential purpose[11] | prevent the liquidity risk due to maturity mismatch | prevent the insolvency risk due to loan default | encourage deleverage and limit balance sheet expansion |
| Means | $\frac{D}{R} \geq r_{RR}$[12] | $\frac{HQLA}{NCOF} \geq r_{LCR}$ | $\frac{C}{RWA} \geq r_{CAR}$ | $\frac{C}{TA} \geq r_{LR}$ |
| Equilibrium expression for money supply | $M_{RR} = \frac{R}{r_{RR}}$ | $M_{LCR} = \begin{cases} \frac{4(R+G)}{\mu r_{LCR}}, \ \mu \leq \frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}}; \\ \frac{(R+G)(1+\theta-r_{LCR})+C}{r_{LCR}[\mu(1+\theta)-1]}, \ \mu > \frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}}. \end{cases}$ | $M_{CAR} = R + G + (\frac{1}{\gamma r_{CAR}} - 1)C.$ | $M_{LR} = (\frac{1}{r_{LR}} - 1)C.$ |
| Equilibrium expression for money multiplier | $m_{RR} = \frac{1}{r_{RR}}$ | $m_{LCR} = \begin{cases} \frac{4(1+\frac{G}{R})}{\mu r_{LCR}}, \ \mu \leq \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}; \\ \frac{(1+\frac{G}{R})(1+\theta-r_{LCR})+\frac{C}{R}r_{LCR}}{r_{LCR}[\mu(1+\theta)-1]}, \ \mu > \frac{4(1+\frac{G}{R})}{(3\theta+3+r_{LCR})(1+\frac{G}{R})-\frac{C}{R}r_{LCR}}. \end{cases}$ | $m_{CAR} = 1 + \frac{G}{R} + (\frac{1}{\gamma r_{CAR}} - 1)\frac{C}{R}.$ | $m_{LR} = (\frac{1}{r_{LR}} - 1)\frac{C}{R}.$ |
| Response of money supply and money multiplier to the shock to monetary base | $\frac{\partial M_{RR}}{\partial R} > 0, \frac{\partial m_{RR}}{\partial R} = 0.$ | $\frac{\partial M_{LCR}}{\partial R} > 0, \frac{\partial m_{LCR}}{\partial R} < 0.$ | $\frac{\partial M_{CAR}}{\partial R} > 0, \frac{\partial m_{CAR}}{\partial R} < 0.$ | $\frac{\partial M_{LR}}{\partial R} = 0, \frac{\partial m_{LR}}{\partial R} < 0.$ |
| Response of money supply and money multiplier to the shock to the concerned minimum policy ratio | $\frac{\partial M_{RR}}{\partial r_{RR}} < 0, \frac{\partial m_{RR}}{\partial r_{RR}} < 0.$ | $\frac{\partial M_{LCR}}{\partial r_{LCR}} < 0, \frac{\partial m_{LCR}}{\partial r_{LCR}} < 0.$ | $\frac{\partial M_{CAR}}{\partial r_{CAR}} < 0, \frac{\partial m_{CAR}}{\partial r_{CAR}} < 0.$ | $\frac{\partial M_{LR}}{\partial r_{LR}} < 0, \frac{\partial m_{LR}}{\partial r_{LR}} < 0.$ |
| Other determinants of money supply | NA | $\frac{\partial M_{LCR}}{\partial \mu} < 0, \frac{\partial M_{LCR}}{\partial G} > 0;$ $\frac{\partial M_{LCR}}{\partial C} > 0, \frac{\partial M_{LCR}}{\partial \theta} < 0, \text{ if } IF < 0.75 * OF.$ | $\frac{\partial M_{CAR}}{\partial G} > 0, \frac{\partial M_{CAR}}{\partial C} > 0,$ $\frac{\partial M_{CAR}}{\partial \gamma} < 0.$ | $\frac{\partial M_{LR}}{\partial C} > 0.$ |
| Other determinants of money multiplier | NA | $\frac{\partial m_{LCR}}{\partial \mu} < 0, \frac{\partial m_{LCR}}{\partial g} > 0;$ $\frac{\partial m_{LCR}}{\partial g} < 0, \frac{\partial m_{LCR}}{\partial c} > 0, \text{ if } IF < 0.75 * OF.$ | $\frac{\partial m_{CAR}}{\partial g} > 0, \frac{\partial m_{CAR}}{\partial c} > 0,$ $\frac{\partial m_{CAR}}{\partial \gamma} < 0.$ | $\frac{\partial m_{LR}}{\partial c} > 0.$ |

[11] Monetary control: changing the required reserve ratio may restrict commercial bank balance sheet growth when reserve money cannot easily be increased, and may influence the spread between deposit and lending rates and thus impact the growth of monetary aggregates and thus inflation; Prudential purpose: reserves provide protection against both liquidity risk. See Simon (2011) for more discussion about the purpose of the reserve requirement.

[12] $r_{RR}$ is the minimum required reserve ratio.

### 4.2 Collective impact of multiple regulations under different economic conditions

> "Regulatory measures must build upon each other and be interlocked to set consistent incentives. Otherwise, we run the risk of individual measures conflicting with each other. Such a lack of consistency might lessen the desired effects of the new regulations or even negate them entirely. Impact studies are an important tool in this context. "
>
> —Dombret (2013), Member of the Executive Board of the Deutsche Bundesbank

Up till now, we have obtained the equilibrium expressions for the broad money supply and the money multiplier when the bank only face one regulation. However, without a comprehensive analysis when multiple policy instruments simultaneously take effects, the evaluation of the impacts of Basel III on money creation is incomplete. When the bank is subject to more than one prudential regulations, its credit creation capacity is binded by the most stringent constraint. Therefore, by comparing the values of the money multiplier derived for each individual instrument in Equations 43,48 and 54 and solving for the minimum money multiplier, we can determine the effective binding regulation and obtain the corresponding expression for the money multiplier when multiple regulations are imposed at the same time, i.e.

$$m = min\{m_{LCR}, m_{CAR}, m_{LR}\}. \tag{57}$$

Correspondingly, the boundary conditions that mark the transitions of the binding constraint can be derived when the expressions for the money multiplier corresponding to either two regulations take the same value. For the sake of simplicity, we denote the ratio of government bonds to reserves as $g = \frac{G}{R}$ and the ratio of bank capital to reserves as $c = \frac{C}{R}$. In specific, the boundary condition between the LCR and CAR regulations is given by

$$\begin{aligned} \frac{4(1+g)}{\mu r_{LCR}} &= 1+g+(\frac{1}{\gamma r_{CAR}}-1)c, \\ or\ \frac{(1+g)(1+\theta-r_{LCR})+cr_{LCR}}{r_{LCR}[\mu(1+\theta)-1]} &= 1+g+(\frac{1}{\gamma r_{CAR}}-1)c. \end{aligned} \tag{58}$$

The boundary condition between the LCR and LR regulations is

$$\begin{aligned} \frac{4(1+g)}{\mu r_{LCR}} &= (\frac{1}{r_{LR}}-1)c, \\ or\ \frac{(1+g)(1+\theta-r_{LCR})+cr_{LCR}}{r_{LCR}[\mu(1+\theta)-1]} &= (\frac{1}{r_{LR}}-1)c. \end{aligned} \tag{59}$$

The boundary condition between the CAR and LR regulations is

$$1+g+(\frac{1}{\gamma r_{CAR}}-1)c=(\frac{1}{r_{LR}}-1)c. \tag{60}$$

For the two expressions for LCR regulation to take identity,

$$\frac{4(1+g)}{\mu r_{LCR}}=\frac{(1+g)(1+\theta-r_{LCR})+cr_{LCR}}{r_{LCR}[\mu(1+\theta)-1]}. \tag{61}$$

Due to the mathematical complexity of the expression for the money multiplier in Equation 57, we set $r_{LCR}=100\%, r_{CAR}=7\%, r_{LR}=3\%$ in the following analyses and use Fig. 4 as the major illustration for analysis. By setting the monetary base to be constant, we focus on the transitions of the effective binding regulation and the relative changes in the equilibrium values of the money multiplier across different economic states and bank balance sheet conditions.

To begin with, we categorize the concerning variables into two groups. The first group includes the variables that determine the features of the bank's uses of funds: the average maturity of loans $\theta$ and the average default risk of loans $\gamma$. The second group contains variables that characterize the bank's sources of funds: the average run-off ratio of bank liabilities $\mu$ and the capital to reserve ratio $c$. For the uses of funds, loans with longer maturity $\theta$ and higher default risk $\gamma$ are often associated with higher profits. Nevertheless, these loans will also expose the bank to greater probabilities of maturity mismatch and insolvency problems. For the source of funds, the debt-financing source is usually stable during good times (low $\mu$) and becomes flighty during economic downturns (high $\mu$). The amount of bank capital, on the other hand, depends on how the bank makes a balance between profitability performance and risk resilience, and on how difficult to raise new equity.

Based on these reasoning, we vary the average maturity $\theta$ and default risk $\gamma$ and show them respectively in the horizontal and vertical axes in all panels in Fig. 4. Correspondingly, the equilibrium values of the money multiplier are presented in color. To discuss the features of the bank's financing sources, we consider three scenarios: 1) the bank holds high level of capital $c=2$ and faces low run-off ratio of debt financing $\mu=0.1$ ; and 2) the bank holds low level of capital $c=0.8$ and faces low run-off ratio of debt financing $\mu=0.1$; and 3) the bank holds high level of capital $c=2$ and faces high run-off ratio of debt financing $\mu=0.55$. For all scenarios, the government bonds to reserve ratio $g$ is kept fixed and equal to 3. Choice of the values of parameter $c$ in these examples is made based on the statistics of the U.S. banking system in the from 1992 to 2009 as shown in Table 3. The exemplary values of parameter $\mu$ are determined based on the estimated run-off ratios for different types of liabilities listed in the official document from the Basel Committee on the liquidity coverage ratio regulation (Basel Committee on Banking Supervision, 2013). It is noteworthy that these scenarios are representative cases while there are other scenarios where the interactions of the three prudential regulations and the values for the money multipliers are different. Yet such differences are in scale, not in type, which will not lead to qualitative changes in our conclusions. Next, we will base our analysis on these three scenarios and demonstrate how the binding regulation changes with economic situation and how the bank's credit creation ability is affected.

Fig. 4(a) presents the benchmark case for Scenario 1 where all three regulations can be the effective binding constraint when the default risk of loans $\gamma$ varies from 0 to 1 and the average loan maturity $\theta$ changes from 1 month to 15 years. When the default risk of loans is high, the bank is binded by the CAR regulation. When the default risk is relative low and average loan maturity is long, the LCR regulation takes effect. When the assets are both low in risk and short in maturity, the LR regulation serves as a backstop constraint on money creation. Also, in consistency with our result on the dependence of the money multiplier on loan maturity and default risk for individual regulations, the money multiplier drops when the bank holds assets with longer maturity and higher default risk. However, due to the piece-wise expression of the money multiplier, the same increment in $\theta$ and $\gamma$ when their values are at different levels may have distinct effects on the value of the multiplier.

In Scenario 2, there is no change in the bank's debt-based financing source but the level of bank capital is much lower than that in Scenario 1. As a result, the capital constraint becomes the bank's biggest concern. As shown in Fig. 4(b), only capital requirements are taking effect. The CAR and LR regulations are respectively responsible for the situations of higher and lower default risk. Compared to the first scenario, the bank's ability to create money significantly drops with the decrease of its capital holdings, as indicated by the lower values of the money multiplier for the same default risk and loan maturity combination in Fig. 4(b) than (a). The money multiplier is negatively dependent on the default risk whereas it is unaffected by changes in the average maturity of loans.

In addition, Fig. 4(c-d) demonstrates the changes of the money multiplier in Scenario 3 where bank capital is sufficient but the run-off ratio of the bank's debt-based fundings is high. In this scenario, regardless of the average maturity and risk of loans, the bank is binded only by the LCR regulation. This result corresponds to the phenomenon of extreme liquidity shortage in the economic downturn when the roll-over of short term debt financing like wholesale funding are unlikely to happen or when depositors or other debtors for the bank start to withdraw funds due to risk aversion during market panic. Even though the bank's capital holdings are still high, we can observe a significant decrease of the money multiplier in Fig. 4(c-d) compared to Fig. 4(a) due to the instability of its debt financing. Moreover, the money multiplier under this situation is only dependent on the length of loan maturity yet such dependence is a discrete function due to the piece-wise definition of the net cash outflow in LCR regulation. To have better illustration, we show the values of the money multiplier under LCR regulation for loan with maturity less than 6 months in (c) and higher than 6 months in (d).

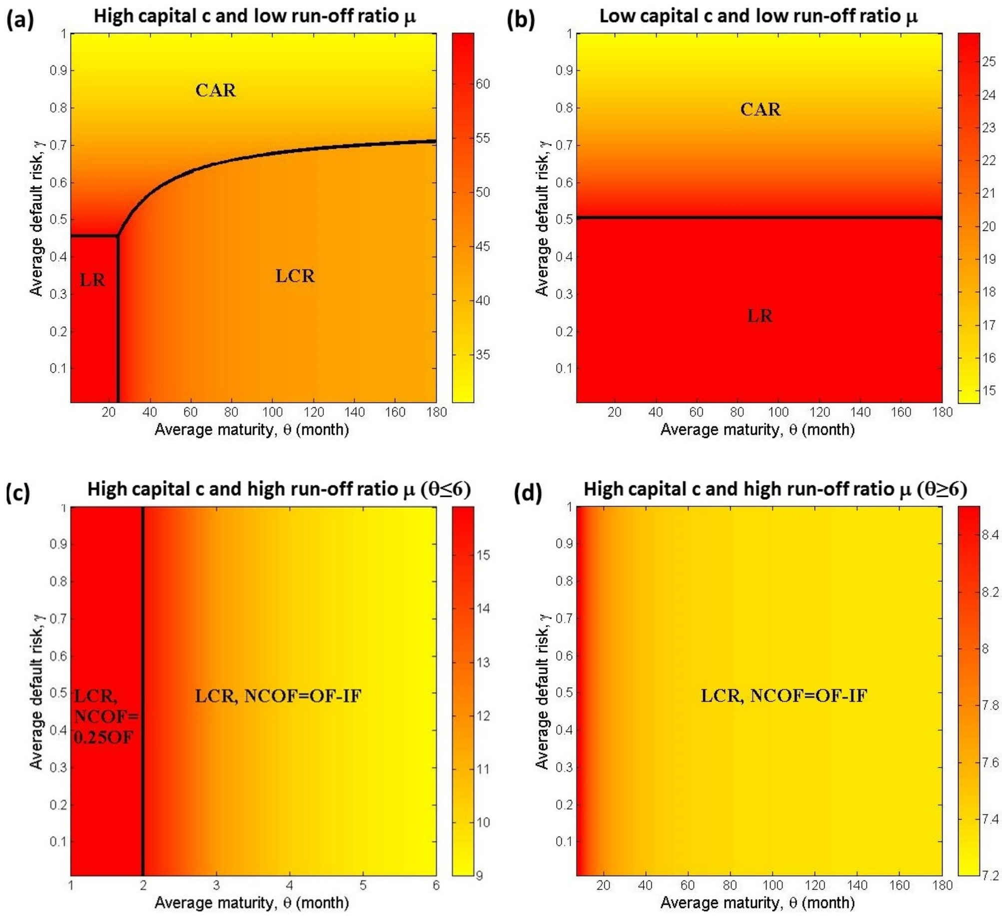


**Figure 4:** Binding regulations and corresponding values of the equilibrium money multiplier as a function of the average default risk $\gamma$ ($\gamma \in [0,1]$) and the average maturity $\theta$ ($\theta \in [1,180]$) of loans under three representative scenarios with different combinations of the capital-to-reserve ratio $c$ and the deposit run-off ratio $\mu$. The values of the money multiplier are computed according to Equation 57 and indicated by color with red representing high values and yellow representing low values. Boundaries between different binding regulations are computed based on Equations 58,59,60,61 and presented by black lines that separate the state space of $\gamma$ and $\theta$. (a) Scenario 1: the bank holds high level of capital with $c = 2$ and faces low run-off ratio $\mu = 0.1$. In this case, all three regulations can be observed in the parameter space of the maturity length $\theta$ and default risk $\gamma$ of loans. (b) Scenario 2: the bank faces low run-off ratio $\mu = 0.1$ but holds low level of capital $c = 0.8$. Only capital requirements can be observed in the parameter space. (c-d) Scenario 3: The bank holds high level of capital $c = 2$ but faces high liability run-off ratio $\mu = 0.55$ with (c) demonstrating results for maturity less than 6 months and (d) for maturity larger than 6 months. All results are obtained for $g = 3$. In both (c) and (d), the LCR regulation alone takes effect. In all three scenarios, the money multiplier is generally higher with high capital holdings, low run-off ratio, low default risk and short maturity length.

As shown in Fig. 4(c), when the average loan maturity is extremely short, i.e. less than 2 months, the net cash outflow is solely determined by the expected cash outflow. In this case, the money multiplier is independent of the average loan maturity and the loan default risk and is generally lower than Scenario 1 and 2. When the average loan maturity is larger than 2 months (Fig. 4(d)), the net cash outflow is governed by the difference between the total cash outflow and cash inflow. In this case, the bank faces large loss in its funding source, and at the same time, have trouble in claiming its own funds back. The money multiplier is a decreasing function of the average loan maturity: for an average maturity of 6 months, the money multiplier has already decreased to less than 9, which is $1/6$ of the maximum value in Scenario 1. Nevertheless, the decline in the multiplier due to the increment of loan maturity for more than 6 months is extremely marginal.

To summarize, when multiple prudential regulations are simultaneously taking effect, we find that 1) the effective binding regulation, by which the bank's ability to create money is constrained, varies across different economic states and bank balance sheet conditions; and 2) due to the transition of the effective binding regulation, the money multiplier depends on the parameters related to the economic state and bank balance sheet condition in a nonlinear way; and 3) in general, the money multiplier gets higher when the banking system holds higher level of capital, assets with shorter maturity and lower default or depreciation risk, and more stable debt-based financing source.

# 5 Concluding remarks

The aim of the Basel III accord is to improve the resilience of the banking system and prevent future crisis. However, it also bears the cost of restricting financial activities and downsizing the loan and money supply by the banking system. This paper focused on the immediate impact of the Basel III accord on the money creation process and provided a comprehensive analysis for the three pillar regulations in the Basel accord, including not only the enhanced risk-based capital adequacy regulation but also the requirements on the leverage ratio and the liquidity coverage ratio. Using both graphical illustration and a dynamic stock-flow consistent model, we elaborated on the central roles of commercial banks in money creation and the mechanism through which prudential regulations affect bank lending and money supply.

For each prudential regulation, we studied their standalone impact on money creation by obtaining the equilibrium expressions for the broad money supply and money multiplier and analyzing their corresponding determinants. We found that the money multiplier, instead of being constant as assumed in the traditional FRT, is a decreasing function of the monetary base under all three prudential regulations. In addition, we demonstrated that the determinants of the banking system's capacity of money creation are regulation-specific, due to the differences in the mechanisms through which different prudential regulations take effect. Specifically, under the LCR regulation, the loosening of the minimum requirement of LCR, the shortening of loan maturity, the enhancement of the stability of the bank's debt financing source, the increase in the bank's holdings of bank capital and government bonds are all possible causes for the increase of the money supply. Under the CAR regulation, what affects the money creation process includes the minimum requirement of CAR, the default risk of loans, the amount of bank capital and government bonds. Lastly, the money supply under the LR requirement alone is solely dependent on the bank's capital holdings. In other words, when the bank only faces the LR regulation, increasing the monetary base will have no impact on the broad money supply. This result echoes the work of Martin et al. (2016) which demonstrate several scenarios where changes in bank reserves will have no or even negative impact on the bank's credit supply. In the more complicated analysis, we considered the simultaneous imposition of all three regulations and how their interactions make a difference in the money creation process. Because the bank's capacity of money creation is binded by the most rigid constraint, the money multiplier under the collective influences of multiple regulations is obtained as the minimum value of the multipliers under each individual regulation, given the same monetary base and other things equal. For three representative scenarios of different financing source conditions for the bank, we demonstrated the transitions of the effective binding regulation and the corresponding changes in the money multiplier when there are variations in the risk and maturity structure of the bank's uses of funds. We found that the money creation capacity of the banking system is generally greater when its sources of funds contain sufficient capital and stable liabilities and its uses of funds are less risky and have short maturity. However, due to the dependence of the effective binding regulation and money multiplier on the economic state and bank balance sheet condition, the same policy action may have distinct consequences in different scenarios, which calls for cautiousness of the policy makers in choosing the appropriate policy instrument.

To sum up, this paper is inspired by the pioneering works on rethinking the roles of the banking system in money creation. We contribute to this line of thoughts by emphasizing the important roles of prudential regulation in money creation and by delineating why and how these regulations take effect. In addition, by providing a detailed theoretical analysis of how Basel III regulations impact on money creation, our work lays the foundation for more complicated studies on the macroeconomic impact of Basel III on economic growth. Also, some implications can be drawn from our results for the unusual collapse of the money multiplier during the recent financial crisis[13]. In particular, we have demonstrated economic conditions where the money multiplier falls with the expansion of the monetary base because the commercial bank is capital or liquidity constrained. Although our conclusions are derived based on specific prudential regulations put forward in the Basel III accord and imposed exogenously on the bank, the liquidity/capital constraints may also rise endogenously from the financial market. In other words, one potential explanation for the sluggish response of bank lending to the expansion of the monetary base is that more lending will add to the bank's risk exposure that requires more liquidity and capital buffers to prevent from bankruptcy, whereas obtaining more liquidity and capital buffers are expensive or difficult for the bank due to the weakening of the underlying economic environment.

Lastly, although the simplicity of the model is considered as a merit in the current analysis, it is also important to be aware of its limitations, including the assumption of representative bank, abstractions of interest rate and non-passive response of other economic entities. An extension of the model into more general stock-flow consistent models incorporating heterogeneous agents and more serious data calibration would be a fruitful possibility for future research.

# Appendix

## A Derivation of Equation 19

Combining Equations 9 and 12, we have

$$
\begin{aligned}
L(2)-L(1) &= LF(1)-RP(1) = LF(1),\\
L(3)-L(2) &= LF(2)-RP(2) = LF(2)-\tfrac{1}{\theta}LF(1),\\
L(4)-L(3) &= LF(3)-RP(3) = LF(3)-\tfrac{1}{\theta}[LF(2)+LF(1)],\\
&\vdots\\
L(\theta+1)-L(\theta) &= LF(\theta)-RP(\theta) = LF(\theta)-\tfrac{1}{\theta}[LF(\theta-1)+LF(\theta-2)+\ldots+LF(1)],\\
L(\theta+2)-L(\theta+1) &= LF(\theta+1)-RP(\theta+1) = LF(\theta+1)-\tfrac{1}{\theta}[LF(\theta)+LF(\theta-1)+\ldots+LF(1)],\\
L(\theta+3)-L(\theta+2) &= LF(\theta+2)-RP(\theta+2) = LF(\theta+2)-\tfrac{1}{\theta}[LF(\theta+1)+LF(\theta)+\ldots+LF(2)],\\
&\vdots\\
L(t-1)-L(t-2) &= LF(t-2)-RP(t-2) = LF(t-2)-\tfrac{1}{\theta}[LF(t-3)+LF(t-4)+\ldots+LF(t-\theta-2)],\\
L(t)-L(t-1) &= LF(t-1)-RP(t-1) = LF(t-1)-\tfrac{1}{\theta}[LF(t-2)+LF(t-3)+\ldots+LF(t-\theta-1)].
\end{aligned}
$$

[13] See Goodhart et al. (2016) for more related discussions on this issue.

Summing these equations up, we have

$$L(t)-L(1)=\begin{cases}L(t-1)+\frac{\theta-1}{\theta}LF(t-2)+\ldots+\frac{1}{\theta}LF(t-1), 2\leq t\leq\theta+1;\\ L(t-1)+\frac{\theta-1}{\theta}LF(t-2)+\ldots+\frac{1}{\theta}LF(t-\theta), t\geq\theta+1.\end{cases} \tag{62}$$

With $L(1)=0$, Equation 62 can be rewritten as

$$L(t)=\begin{cases}\sum_{t'=1}^{t-1}\frac{\theta-t'+1}{\theta}LF(t-t'), 2\leq t\leq\theta+1;\\ \sum_{t'=1}^{\theta}\frac{\theta-t'+1}{\theta}LF(t-t'), t\geq\theta+1.\end{cases} \tag{63}$$

Combining Equation 63 with Equation 15 and 17, we have : $\forall t\geq t^*\geq\theta+1$,

$$L(t)=L^*=\sum_{t'=1}^{\theta}\frac{\theta-t'+1}{\theta}LF(t)=\frac{1+\theta}{2}LF^*=\frac{1+\theta}{2}RP^*. \tag{64}$$

In other words,

$$LF(t)=RP(t)=LF^*=\frac{2}{1+\theta}L^*, t\geq t^*. \tag{65}$$

# B Rewriting the conditions of $IF^*\geq 0.75OF^*$ and $IF^*<0.75OF^*$ as a function of $\mu,\theta,g$ and $c$

For the first condition, $IF\geq 0.75OF$, we should have

$$\begin{aligned}\frac{L^*}{1+\theta}&\geq 0.75\mu D^*\\ \Rightarrow\frac{D^*-(R+G-C)}{1+\theta}&\geq 0.75\mu D^*\\ \Rightarrow[1-0.75\mu(1+\theta)]D^*&\geq R+G-C.\end{aligned} \tag{66}$$

For Equation 66 to hold, we should always have $1-0.75\mu(1+\theta)>0$, i.e. $\mu<\frac{4}{3(1+\theta)}$. Substituting the corresponding expression for the equilibrium deposits under this condition, $D^*=\frac{4(R+G)}{\mu r_{LCR}}$, into Equation 66, we have

$$\begin{aligned}[1-0.75\mu(1+\theta)]\frac{4(R+G)}{\mu r_{LCR}}&\geq R+G-C\\ \Rightarrow\mu&\leq\frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}},\end{aligned} \tag{67}$$

where $\frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}} < \frac{4}{3(1+\theta)}$ always holds because

$$\begin{aligned} & \frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}} - \frac{4}{3(1+\theta)} \\ = & \frac{4r_{LCR}(c-1-g)}{3(1+\theta)[(3\theta+3+r_{LCR})(1+g)-cr_{LCR}]} < 0. \end{aligned} \tag{68}$$

Therefore, the first condition of $IF \geq 0.75OF$ is equivalent to $\mu \leq \frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}}$. Correspondingly, the second condition of $IF < 0.75OF$ can be replaced by $\mu > \frac{4(1+g)}{(3\theta+3+r_{LCR})(1+g)-cr_{LCR}}$.

# C The more generalized expressions for the money supply and money multiplier under the LCR regulation after relaxing the assumption of 50% inflow rate for bank loans

This assumption of 50% inflow rate for bank loans used in Equation 25 can be relaxed by the following equation:

$$IF(t) = \omega * RP(t), \tag{69}$$

where $\omega$ is denoted as the inflow rate of the repayments for outstanding bank loans. $\omega$ is generally higher when the counterparty to which bank loans are made has higher credit ratings and can successfully fulfil its debt obligations in stressed condition. Following similar procedures elaborated in Section 4.1, we can obtain the corresponding expressions for the money supply $M$ and money multiplier $m$ when the bank is constrained by the LCR regulation, i.e.

$$M_{LCR} = \begin{cases} \frac{4(R+G)}{\mu r_{LCR}}, \ \mu \leq \frac{8\omega(1+g)}{(3\theta+3+2\omega r_{LCR})(1+g)-2\omega c r_{LCR}}; \\ \frac{(R+G)(1+\theta-2\omega r_{LCR})+2\omega r_{LCR}C}{r_{LCR}[\mu(1+\theta)-2\omega]}, \ \mu > \frac{8\omega(1+g)}{(3\theta+3+2\omega r_{LCR})(1+g)-2\omega c r_{LCR}}. \end{cases} \tag{70}$$

$$m_{LCR} = \begin{cases} \frac{4(1+g)}{\mu r_{LCR}}, \ \mu \leq \frac{8\omega(1+g)}{(3\theta+3+2\omega r_{LCR})(1+g)-2\omega c r_{LCR}}; \\ \frac{(1+g)(1+\theta-2\omega r_{LCR})+2\omega c r_{LCR}}{r_{LCR}[\mu(1+\theta)-2\omega]}, \ \mu > \frac{8\omega(1+g)}{(3\theta+3+2\omega r_{LCR})(1+g)-2\omega c r_{LCR}}. \end{cases} \tag{71}$$

It is straightforward to know that if $\mu > \frac{8\omega(1+g)}{(3\theta+3+2\omega r_{LCR})(1+g)-2\omega c r_{LCR}}$ (i.e. $IF < 0.75 * OF$), then $\frac{\partial M}{\partial \omega} > 0$, $\frac{\partial m}{\partial \omega} > 0$. In other words, if bank loans are made to borrowers with higher credit ratings who can provide larger cash inflows for the bank during stressed condition, the banking system has greater capacity to create money when constrained by the LCR regulation.

# D Calibration of model parameter based on historical data for the U.S. banking system

**Table 3:** Historical data of capital and reserves for the U.S. banking system

| **Year** | $R$ **($ billion)** | $C$**($ billion)** | $CET1$**($ billion)** | $C/R$ | $CET1/R$ |
|---|---|---|---|---|---|
| 1992 | 298 | 263 | 246 | 0.88 | 0.83 |
| 1993 | 273 | 297 | 277 | 1.09 | 1.01 |
| 1994 | 304 | 312 | 287 | 1.03 | 0.94 |
| 1995 | 307 | 350 | 318 | 1.14 | 1.04 |
| 1996 | 336 | 376 | 329 | 1.12 | 0.98 |
| 1997 | 355 | 418 | 354 | 1.18 | 1.00 |
| 1998 | 357 | 462 | 379 | 1.29 | 1.06 |
| 1999 | 366 | 480 | 378 | 1.31 | 1.03 |
| 2000 | 370 | 530 | 423 | 1.43 | 1.14 |
| 2001 | 390 | 594 | 469 | 1.52 | 1.20 |
| 2002 | 384 | 647 | 517 | 1.68 | 1.35 |
| 2003 | 387 | 692 | 527 | 1.79 | 1.36 |
| 2004 | 388 | 850 | 568 | 2.19 | 1.46 |
| 2005 | 400 | 912 | 604 | 2.28 | 1.51 |
| 2006 | 433 | 1030 | 666 | 2.38 | 1.54 |
| 2007 | 482 | 1143 | 715 | 2.37 | 1.48 |
| 2008 | 1042 | 1154 | 755 | 1.11 | 0.72 |
| 2009 | 976 | 1332 | 918 | 1.36 | 0.94 |
| **Mean** | 436.00 | 657.89 | 485.00 | 1.51 | 1.14 |
| **Min** | 273 | 263 | 246 | 0.88 | 0.72 |
| **Max** | 1042 | 1332 | 918 | 2.38 | 1.54 |

**Notes**: This table provides the historical data of reserves and capital for the U.S. banking system from 1992 to 2009 used for the calibration of the model parameter $c$, the capital-to-reserve ratio. Data are obtained by author based on the work of Slovik and Cournède (2011). Based on the ratio of bank capital to reserves ($C/R$) and the ratio of core-Tier 1 capital to reserves ($CET1/R$), we determine that $c = 0.8$ corresponds to relatively low capital positions and $c = 2$ indicates relatively high capital positions.

# Acknowledgment

This work was supported by the Fundamental Research Funds for the Central Universities (Grant No.2015KJJCA06).

# References


Abdul Karim, Z., Azman-Saini, W., and Abdul Karim, B. (2011). Bank lending channel of monetary policy: Dynamic panel data study of Malaysia. Journal of Asia-Pacific Business, 12(3): 225–243.

Ábel, I., Lehmann, K., and Tapaszti, A. (2016). The controversial treatment of money and banks in macroeconomics. Financial and Economic Review, 15(2).

Aiyar, S., Calomiris, C. W., and Wieladek, T. (2016). How does credit supply respond to monetary policy and bank minimum capital requirements? European Economic Review, 82: 142–165.

Albertazzi, U., and Marchetti, D. J. (2010). Credit supply, flight to quality and evergreening: an analysis of bank-firm relationships after Lehman. Discussion paper 756, Bank of Italy.

Alessandri, P., and Haldane, A. G. (2011). Banking on the State. In The International Financial Crisis: Have the Rules of Finance Changed?, pages 169–195. World Scientific.

Allen, B., Chan, K. K., Milne, A., and Thomas, S. (2012). Basel III: Is the cure worse than the disease? International Review of Financial Analysis, 25: 159–166.

Altunbaş, Y., Fazylov, O., and Molyneux, P. (2002). Evidence on the bank lending channel in Europe. Journal of Banking & Finance, 26(11): 2093–2110.

Angelini, P., Clerc, L., Cúrdia, V., Gambacorta, L., Gerali, A., Locarno, A., Motto, R., Roeger, W., Van den Heuvel, S., and Vlček, J. (2015). Basel III: Long-term Impact on Economic Performance and Fluctuations. The Manchester School, 83(2): 217–251.

Basel Committee on Banking Supervision (2011). Basel III: A global regulatory framework for more resilient banks and banking systems. Bank for International Settlements.

Basel Committee on Banking Supervision (2013). The Liquidity Coverage Ratio and liquidity risk monitoring tools. Bank for International Settlements.

Bernanke, B. (2007). The financial accelerator and the credit channel. Speech 296, Board of Governors of the Federal Reserve System (U.S.).

Blundell-Wignall, A., and Roulet, C. (2013). Business models of banks, leverage and the distance-to-default. OECD Journal: Financial Market Trends, 2012(2): 7–34.

Botos, K. (2016). Money Creation in the Modern Economy. Public Finance Quarterly, 61(4): 442–457.

Bridges, J., Gregory, D., Nielsen, M., Pezzini, S., Radia, A., and Spaltro, M. (2014). The impact of capital requirements on bank lending. Working paper 486, Bank of England.

Caiani, A., Godin, A., Caverzasi, E., Gallegati, M., Kinsella, S., and Stiglitz, J. E. (2016). Agent based-stock flow consistent macroeconomics: Towards a benchmark model. Journal of Economic Dynamics and Control, 69: 375–408.

Carpenter, S., and Demiralp, S. (2012). Money, reserves, and the transmission of monetary policy: Does the money multiplier exist? Journal of macroeconomics, 34(1): 59–75.

Chami, R., and Cosimano, T. F. (2010). Monetary policy with a touch of Basel. Journal of Economics and Business, 62(3): 161–175.

Dermine, J. (2013). Bank regulations after the global financial crisis: Good intentions and unintended evil. European Financial Management, 19(4): 658–674.

Disyatat, P. (2011). The bank lending channel revisited. Journal of money, Credit and Banking, 43(4): 711–734.

Dombret, A. (2013). Total Impact-How regulation and crisis management will change the world's financial landscape. Speech, Deutsche Bundesbank, Frankfurt Finance Summit.

Farag, M., Harland, D., and Nixon, D. (2013). Bank capital and liquidity. Working paper, Bank of England.

Francis, W., and Osborne, M. (2009). Bank regulation, capital and credit supply: measuring the impact of prudential standards. Occasional paper 36, UK Financial Services Authority.

Francis, W. B., and Osborne, M. (2012). Capital requirements and bank behavior in the UK: Are there lessons for international capital standards? Journal of Banking & Finance, 36(3): 803–816.

Fullwiler, S. T. (2012). An endogenous money perspective on the post-crisis monetary policy debate. Review of Keynesian Economics, 1(2): 171–194.

Furfine, C. (2001). Bank portfolio allocation: The impact of capital requirements, regulatory monitoring, and economic conditions. Journal of Financial Services Research, 20(1): 33–56.

Gambacorta, L., and Marques-Ibanez, D. (2011). The bank lending channel: lessons from the crisis. Economic Policy, 26(66): 135–182.

Gambacorta, L., and Mistrulli, P. E. (2004). Does bank capital affect lending behavior? Journal of Financial intermediation, 13(4): 436–457.

Goodhart, C. (2015). Why Monetary Policy has Been Comparatively Ineffective? The Manchester School, 83(S1): 20–29.

Goodhart, C., Bartsch, E., and Ashworth, J. (2016). Central banks and credit creation: the transmission channel via the banks matters. Why do societies need independent central banks? 21, page 55.

Goodhart, C. A. (2010). Money, credit and bank behaviour: need for a new approach. National Institute Economic Review, 214(1): F73–F82.

Goodhart, C. A., Kashyap, A. K., Tsomocos, D. P., and Vardoulakis, A. P. (2013). An integrated framework for analyzing multiple financial regulations. International Journal of Central Banking, 9(1): 109–143.

Haldane, A. (2015). Multi-polar regulation. International Journal of Central Banking, 11(3): 385–401.

Honda, Y. (2004). Bank capital regulations and the transmission mechanism. Journal of Policy Modeling, 26(6): 675 – 688.

Horváth, R., Seidler, J., and Weill, L. (2014). Bank capital and liquidity creation: Granger-causality evidence. Journal of Financial Services Research, 45(3): 341–361.

Jakab, Z., and Kumhof, M. (2015). Banks are not intermediaries of loanable funds–and why this matters. Working paper 529, Bank of England.

Jiménez, G., and Ongena, S. (2012). Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications. The American Economic Review, 102(5): 2301–2326.

Keen, S. (2011). Debunking Economics–Revised and Expanded Edition: The Naked Emperor Dethroned? Zed Books.

Kishan, R. P., and Opiela, T. P. (2000). Bank size, bank capital, and the bank lending channel. Journal of Money, Credit and Banking, pages 121–141.

Kishan, R. P., and Opiela, T. P. (2006). Bank capital and loan asymmetry in the transmission of monetary policy. Journal of Banking & Finance, 30(1): 259–285.

Komáromi, A. (2007). The effect of the monetary base on money supply–Does the quantity of central bank money carry any information? MNB Bulletin (discontinued), 2(1): 31–37.

Krug, S., Lengnick, M., and Wohltmann, H.-W. (2015). The impact of Basel III on financial (in) stability: an agent-based credit network approach. Quantitative Finance, 15(12): 1917–1932.

Li, B., Xiong, W., Chen, L., and Wang, Y. (2017). The impact of the liquidity coverage ratio on money creation: A stock-flow based dynamic approach. Economic Modelling.

Loutskina, E., and Strahan, P. E. (2009). Securitization and the declining impact of bank finance on loan supply: Evidence from mortgage originations. The Journal of Finance, 64(2): 861–889.

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

Martynova, N. (2015). Effect of bank capital requirements on economic growth: a survey. Working paper 467, De Nederlandsche Bank.

McLeay, M., Radia, A., and Thomas, R. (2014). Money creation in the modern economy. Quarterly Bulletin Q1, Bank of England.

Mésonnier, J.-S., and Monks, A. (2014). Did the EBA capital exercise cause a credit crunch in the euro area? Working paper 491, Bank of England.

Miles, D., Yang, J., and Marcheggiano, G. (2013). Optimal bank capital. The Economic Journal, 123(567): 1–37.

Moore, B. J. (1988). Horizontalists and verticalists: the macroeconomics of credit money. Cambridge University Press.

Nachane, D. M., Ghosh, S., and Ray, P. (2006). Basel II and Bank Lending Behaviour: Some Likely Implications for Monetary Policy. Economic and Political Weekly, 41(11): 1053–1058.

Noss, J., and Toffano, P. (2014). Estimating the impact of changes in bank capital requirements during a credit boom. Working paper, Bank of England.

Palley, T. I. (1994). Competing views of the money supply process: theory and evidence. Metroeconomica, 45(1): 67–88.

Panagopoulos, Y. (2010). Basel II and the money supply process: some empirical evidence from the Greek banking system. Applied Economics Letters, 17(10): 973–976.

Peek, J., and Rosengren, E. (1995a). Bank regulation and the credit crunch. Journal of Banking & Finance, 19(3): 679–692.

Peek, J., and Rosengren, E. (1995b). The capital crunch: Neither a borrower nor a lender be. Journal of Money, Credit and Banking, 27(3): 625–638.

Peek, J., and Rosengren, E. S. (1997). The International transition of financial shocks: the case of Japan. The American Economic Review, 87(4): 495–505.

Peek, J., and Rosengren, E. S. (2010). The role of banks in the transmission of monetary policy. In J. O. S. W. Allen N. Berger, Philip Molyneux (Ed.), The Oxford Handbook of Banking. Oxford: Oxford University Press.

Puri, M., Rocholl, J., and Steffen, S. (2011). Global retail lending in the aftermath of the US financial crisis: Distinguishing between supply and demand effects. Journal of Financial Economics, 100(3): 556–578.

Quinaz, P. D., and Curto, J. D. (2016). Prudential regulation in an artificial banking system. Economics, 10(31): 1.

Ryan-Collins, J., Greenham, T., Werner, R., and Jackson, A. (2012). Where does money come from. A guide to the UK monetary and banking system, 2.

Simon, G. (2011). Central Bank Balances and Reserve Requirements. Working paper, International Monetary Fund.

Slovik, P., and Cournède, B. (2011). Macroeconomic impact of Basel III.

Van den Heuvel, S. J. (2002a). The bank capital channel of monetary policy. The Wharton School, University of Pennsylvania, mimeo, pages 2013–14.

Van den Heuvel, S. J. (2002b). Does bank capital matter for monetary transmission? Economic Policy Review, 8(1): 259–265.

VanHoose, D. (2007). Theories of bank behavior under capital regulation. Journal of Banking & Finance, 31(12): 3680–3697.

Werner, R. A. (2014). Can banks individually create money out of nothing?The theories and the empirical evidence. International Review of Financial Analysis, 36: 1–19.

Xiong, W., Li, B., Wang, Y., and Stanley, H. E. (2017). The versatility of money multiplier under Basel III regulations. Working paper.

Yan, M., Hall, M. J., and Turner, P. (2012). A cost–benefit analysis of Basel III: Some evidence from the UK. International Review of Financial Analysis, 25: 73–82.