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Research article

Bank regulation induced new credit channels and obscure obstruction of monetary transmission

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Abstract: In response to the financial crisis, some central banks have employed quantitative easing policies to stimulate economic recovery. Furthermore, stringent bank regulatory policies were introduced to ensure economic stability. The interplay between these measures has raised concerns about the effectiveness of monetary transmission. We aimed to examine the credit creation of banks with bank regulations and how these regulations reshape the transmission of monetary policy through bank lending. The results revealed that each bank regulatory requirement forms a maximum amount of credit, named as a credit capacity, which constrains credit creation of banks. Additionally, banks would reconstruct the balance sheets as a response to these regulations. Thus, bank regulations can reshape bank lending via the following two ways. Firstly, with the influence of bank regulations on bank lending, new monetary channels emerge, including new bank capital, new risk-taking, new bank lending, and new bank balance sheet channels. Specifically, the new bank capital channel refers to monetary shocks changing the amount of bank capital, which is subject to the CAR and LR regulations and affects bank lending via corresponding credit capacity. The new risk-taking channel is also related to the CAR regulation, which results in a variation in credit capacity due to changes in the bank's weighting parameters of risky assets. Both the new bank lending and new bank balance sheet channels are transmitted via the credit capacity formed by multiple bank regulations. Secondly, we proposed some plausible obstacles in the monetary transmission and analyzed the reasons for their formation. When banks' credit creation is subject to multiple bank regulations, the credit capacity is determined by the tightest bank regulation. As the tightest one shifts between various bank regulations, the bank credit base also undergoes constant changes. Only when a monetary shock effectively increases the credit base corresponding to the tightest regulations can the bank's credit capacity increase, ensuring the effectiveness of monetary policy; otherwise, obstacles may arise. The empirical results showed that after the financial crisis, capital regulation has become the tightest constraint to the expansion of bank

credit. We believe that our theoretical findings can lay a new foundation for designing effective monetary policy.

Keywords: monetary transmission; credit capacity; credit creation; bank regulation

JEL Codes: E10, E43, E44, E51, E52, E58, G21, G28

1. Introduction

Interest rates are the traditional tool of central banks to achieve the goal of monetary policy. As interest rates have decreased to a "zero lower bound" since the financial crisis of 2008, the conventional price-target monetary policy has become ineffectual (Sellon, 2003; Schmidt, 2013). As a result, central banks have introduced a set of quantitative easing monetary policies to stimulate economic recovery. However, implementing these unconventional monetary policies has not led to a full recovery of aggregate output but rather to a "secular stagnation" (Summers, 2015).

This indicates that monetary policy might encounter obstacles in the transmission process from a policy shock to aggregate demand, prompting many economists to explore the reasons behind these obstacles in monetary transmission. The monetary transmission involves various agents and markets, with the most common scenarios and reasons for identifying obstacles being the operational failure of commercial banks in the money market. Abbassi and Linzert (2012) focus on the transmission effects on the Fed funds rate, particularly after the financial crisis. The result shows that with the decrease in the fed funds rate, there is a lack of smoothness in the transmission within the money market. Eisenschmidt et al. (2024) suggest that the dealer market power can influence the transmission of monetary policy by the European Central Bank, leading to inefficiencies in the transmission of the interest rate channel. While these studies analyze transmission obstacles in the money market from various perspectives, they overlook the pivotal role of commercial banks in the monetary policy transmission process. Unlike other financial institutions in the money market, only commercial banks can extend deposit money to borrowers by credit creation. The fundamental objective of monetary policy is to stimulate or regulate the credit creation of the banking system, implying the undeniable importance of bank credit. Therefore, in addition to the processes mentioned in existing research, greater attention should be paid to those factors influencing the bank credit creation. Bank regulation plays a crucial role in affecting the amount of bank credit. In this paper, we seek the reasons for the obstruction in the transmission of monetary policy by examining the impact of bank regulations on transmission channels. In the decades preceding the 2008 global financial crisis, the world experienced an era of unprecedented financial globalization, characterized by the dismantling of capital controls, the cross-border integration of banking systems, and the exponential growth of derivative markets (Cetorelli and Linda, 2010; Lane, 2013). During this period, banks engaged in aggressive lending practices, particularly in the housing market, driven by low interest rates and relaxed lending standards. This led to a housing boom and the subsequent packaging and resale of mortgages as complex financial products, such as mortgage-backed securities (Acharya and Richardson, 2009). The deregulation of the financial industry further exacerbated the situation, allowing institutions to operate with minimal accountability and fostering an environment where high-risk behaviors were prevalent. These factors collectively precipitated the financial crisis, thereby underscoring the necessity for stringent financial

regulations. In the aftermath of the 2008 financial crisis, to ensure the stability of banks and the financial system, BCBS Basel III (2010; 2013) strengthened bank capital regulations (CAR and LR) and introduced liquidity regulations (NSFR and LCR). These regulations impacted the structure of banks' balance sheets and limited credit availability (VanHoose, 2007; Martynova, 2015; Muduli and Behera, 2020). Furthermore, the primary goal of the central banks is to prevent the economy from plunging into further crisis by boosting aggregate demand through a massive quantitative easing. Balancing the conflicting goals of banking regulation and monetary policy has become a priority for policymakers and economists (VanHoose, 2008; Angeloni and Faia 2013; Agénor and Silva, 2014). Duffie and Krishnamurthy (2016) concentrate on the negative impacts of capital regulations, including LR and CAR requirements, on the transmission of monetary policy through money markets. Dombret (2013) takes into account the interplay between different capital and liquidity restrictions, emphasizing the need for coordination and consistency of goals to guarantee the efficacy of monetary policy. Besides, Xiong and Wang (2022) examine the nonlinear and non-monotonic results of bank lending channel under different prudential regulations. We recognize that banks are not only the credit creators, but also the suppliers of funds. The amount of bank lending is determined by supply and demand in the funds market.

In this paper, we assume that the constraints of regulatory requirements are imposed on banks' credit creation and thus govern the provision of funds. Therefore, the transmission mechanism of monetary policy through banks has also changed accordingly. Our focus is on understanding the impact of changes in the supply side on the volume of bank lending. In this paper, we address the following two issues:

1. What impact do multiple banking regulations have on banks' credit creation, and how do banks determine the supply of funds under such circumstances?
2. How do regulation-induced changes in banks' decisions affect monetary transmission channels, and what effects do monetary shocks have under these regulations?

While we recognize that banks are the suppliers of funds by credit creation, and the amount of bank lending is influenced by both supply and demand in the funds market, we focus on understanding the impact of changes in the supply side on the volume of bank lending. This implies that, in this paper, the tightest constraint is assumed to lie on the supply side of the funds market, and the result of bank lending is governed only by the funds it can provide.

The contributions of this paper can be summarized as follows:

1. We examine how bank regulations influence the transmission of monetary policy and reformulate transmission channels.
2. Considering the impact of bank regulations, we propose the concept of credit base and credit capacity to analyze the decision of bank lending.
3. We find that only the transmission channel of monetary policy corresponding to the tightest regulatory constraint is effective, while other channels may be obstructed.
4. Through empirical analysis, we prove that bank regulations would yield obstruction of monetary transmission and suggested the theoretical foundation for a better design of monetary policy.

The structure of this paper is as follows. In Section 2, we review of traditional monetary transmission via banks. Section 3 includes the impact of bank regulations on credit capacity. Section 4 contains the induced monetary transmission under some typical bank regulations. In Section 5, we identify the obstruction of monetary transmission. In Section 6, we present the empirical results. In Section 7, we conclude the paper.

2. The review of traditional monetary transmission via banks

After the financial crisis, economists have shifted their focus on the role of banks in the macroeconomy and attempted to integrate them into standard macroeconomic models (Gertler and Karadi, 2011; Dia and VanHoose, 2017). The interdependence between monetary policy and the state of the banking system has also been studied (De Graeve et al., 2008). The banking sector is the primary part of the monetary transmission, and the ability of banks to effectively regulate the supply of funds to other sectors of the economy is the key factor for policymakers to achieve their objectives. Currently, the classical transmission channels of monetary policy via banks can be summarized as the bank lending channel, the bank balance sheet channel, the bank capital channel, and the bank risk-taking channel, as shown in Table 1. The bank lending channel and the bank balance sheet channel are two components of the credit channel, and the mechanism by which they work is that changes in the supply of bank credit affect aggregate demand (Bernanke and Gertler, 1995). Specifically, the traditional bank lending channel refers to how monetary policy such as required reserve ratio changes the number of deposits, which is a financing source for bank lending, resulting in a corresponding decrease in the amount of loans. For the traditional balance sheet channel, it has two versions; the primary version emphasized the impact of monetary policy shocks on a firm's balance sheets (Townsend, 1979; Angelopoulou and Gibson, 2009). After realizing the significance of banks in macroeconomics, economists discovered that monetary policy shocks also impacted banks' balance sheet structure. As a result, research on the connection between monetary policy and the structure of banks' balance sheets began to emerge, which led to the introduction of the bank balance sheet channel (Jiménez et al., 2012; Kapan and Minoiu, 2018; Cetorelli and Goldberg, 2016). When banks encounter a shock of monetary policy, the balance sheet structure of banks will change with the influence of the purpose of maximizing bank profits, which will impact aggregate demand. For the traditional bank capital channel, the mechanism of this channel is closely related to the bank lending channel, with a key distinction being that monetary policy acts on bank capital than deposits to influence aggregate demand (Rasche and Johannes, 1987). In the context of the bank capital channel, changes in monetary policy led to changes in net interest margins, and ultimately influenced bank capital (Gambacorta and Mistrulli, 2004; Chami and Cosimano, 2010; Orzechowski, 2019). Bank capital will have different results on bank credit under different capital supervision policies and risk-based capital standards (Honda, 2004; Kopecky and VanHoose, 2004). As research on the bank capital channel deepens and the formulation of bank capital regulations, some literature introduces the risk-taking channel (Rajan, 2006; Borio and Zhu, 2012). This channel highlights that in a low-interest-rate environment, banks' net interest margins shrink as the decline in asset-side yields is more significant. To sustain profitability, banks shift toward higher-risk assets.

Moreover, based on the existing monetary policy literature, many scholars have made some extensions and proposed a few new transmission channels of monetary policy (Berger and Bouwman, 2017; Berger et al., 2019; Drechsler et al., 2017). Some economists also empirically verify the variability of the transmission of existing monetary policy channels among countries (Hernando and Martínez-Pagés, 2001; Dang and Huynh, 2021; Dang and Huynh, 2022; Ciccarelli et al., 2015). However, most empirical research demonstrates that there is no consensus regarding the precise effect of monetary transmission across different empirical works because of variations in data and analysis methodologies.

Table 1. Summary of traditional transmission channels of monetary policy via banks.

The role of banks	Financial intermediaries			
	Traditional bank lending channel	Traditional bank balance sheet channel	Traditional bank capital channel	Traditional risk-taking channel
Causality	Monetary shock → changes in deposits → changes in loans.	Monetary shock → changes in the structure of balance sheet → changes in bank profit → changes in loans.	Monetary shock → changes in the interest rate spread → changes in the level of bank capital → changes in deposits → changes in loans.	Monetary shock → changes in the interest rate → changes in the value of assets and collateral → changes in the perception of future volatility and risk → changes in evaluation of risks for banks → changes in the level of risk-taking.

3. The impact of bank regulations on credit capacity

Banks are regarded as financial intermediaries in the traditional transmission channels of monetary policy. The intermediary theory of banking emphasizes that the role of banks is collecting deposits and making loans (Tobin, 1963; Martinez-Miera and Suarez, 2012). Therefore, the logic chain of traditional monetary transmission is "monetary shock → changes in deposits → changes in loans". The long-dominant theory of bank intermediary has faced criticism in explaining and responding to the negative effects of the financial crisis (Jakab and Kumhof, 2015a, 2015b). The credit creation theory of banking, which has gained increasing recognition, posits that banks play a crucial role in credit and money creation by demonstrating that deposits are the product of bank lending rather than a prerequisite of lending activities (Moore, 1988; Carpenter and Demiralp, 2012; Werner, 2014). When a bank makes a loan, it simply creates a corresponding deposit in the borrower's account without pre-existing deposits.

According to McLeay et al. (2014), the ability of banks to create credit does not indicate that there is no ceiling on the number of loans. The management of risks by banks and the potential constraints posed by bank regulations can influence the amount of loans. In this section, we identify how bank regulations affect banks' credit creation, and in particular, the capacity formed. Honda (2004) distinguished monetary and debt channels via banks by including bank regulations in the analysis of the money creation process. To examine the impact of bank regulations on credit creation, Li et al. (2017) took the requirement of the liquidity coverage ratio as an example and reformulated the money multiplier in terms of regulatory requirements. The research on the mechanism of money creation was expanded by Xiong et al. (2020) to include multiple bank regulations, and they found that the money supply of banks with multiple regulations relies on the strictest constraint. Additionally, Xing et al. (2020) examined how multiple regulations affect money creation by considering the heterogeneity of banks. Zhong et al. (2024) provided multiple channels for monetary policy transmission to aggregate demand through decomposing aggregate demand in terms of stocks.

Based on the conclusions regarding the impact of bank regulations on credit creation, we introduce a concept of credit capacity, defined as the maximum amount of loans that the banking sector can create. Bank regulations influence the credit capacity by shaping the corresponding credit base and

influencing the actual volume of credit creation. When regulatory requirements are intensified, the corresponding credit capacities would be reduced. Specifically, the credit base tied to the CAR and LR regulations within Basel III is the capital of the bank. A decrease in this base leads to a reduction in credit capacity. Similarly, the credit base influenced by LCR regulations, such as reserves and government bonds, also decreases, causing a decline in credit capacity. The credit base of RR regulation is reserves, and thus, a decrease in reserves results in a reduction of credit capacity.

To facilitate the analysis, we assume that the assets of a highly simplified balance sheet include only reserves (R) and loans (L), and the liability includes deposits (D) as well as equity (E). These stock items on the balance sheet must meet the following identity: R + L = D + E. In this part, we take the CAR regulation as an example to analyze the corresponding expression of credit capacity. The definition of CAR is the ratio of capital to risk-weighted assets (RWA), which can be written as

$$\mathrm{CAR} = \frac{\text{Tier1 capital} + \text{Tier2 capital}}{\mathrm{RWA}}, \tag{1}$$

where the numerator represents the total capital over two classes. According to the CAR regulation, different categories of capital correspond to different standards of capital adequacy. We assume that all bank capitals can be regarded as the same when examining the impact of CAR regulation on credit capacity. Thus, the requirement of capital adequacy can be expressed as,

$$\frac{\mathrm{E}}{\mathrm{RWA}} \geq \mathrm{CAR}_{\min}, \tag{2}$$

where the term RWA refers to the total assets, in which each class is weighted by a risk coefficient. In the highly simplified balance sheet, the asset side contains only loans and reserves. As the reserves are highly liquid and safe assets, the expression of RWA in our model is given as follows (Xiong and Wang, 2022).

$$\mathrm{RWA} = \gamma * \mathrm{L} + 0 * \mathrm{R}, \tag{3}$$

where γ stands for the risk-weighted coefficient of loans. While that of reserves is set to be 0 in our model. Substituting Equation (3) into Equation (2), we can obtain,

$$\frac{\mathrm{E}}{\gamma * L} \geq \mathrm{CAR}_{\min}, \tag{4}$$

When the inequality is replaced with equality, we can derive the expression for the credit capacity corresponding to the CAR regulation, which is given by (Xiong et al., 2020; Xing et al., 2020)

$$\mathrm{L}_{\mathrm{MAX}}^{\mathrm{CAR}} = \frac{\mathrm{E}}{\gamma * \mathrm{CAR}_{\min}}, \tag{5}$$

The result indicates that credit capacity and $\mathrm{CAR}_{\min}$ have an inverse relationship, meaning that a stringent bank regulation results in a reduction in banks' ability to extend credit.

Similarly, based on banks' credit creation and their balance sheet context, various expressions of credit capacity corresponding to different requirements, including the required reserve ratio, leverage ratio, and liquidity coverage ratio, can be derived. The effect of the required reserve ratio regulation on credit capacity is as follows: When the central bank sets a required reserve ratio, the proportion of reserves held by the banks should be greater than the minimum reserve ratio set by the central bank.

The maximum volume of deposits under the required reserve ratio is equal to the reciprocal of the required reserve ratio multiplied by the amount of reserves it holds. In addition, combining with the identity equation of the balance sheet, we can obtain the bank's credit capacity under the requirement of the reserve ratio. The leverage ratio regulation works by the capital adequacy ratio by placing restrictions on the proportional relationship between bank capital and total assets. The expression of credit capacity under leverage ratio regulation can be simply derived with loans and reserves as the components of assets (Xiong et al., 2020; Xing et al., 2020). The liquidity regulation, which was first put forward in the Basel Accord in the wake of the 2008 financial crisis, focuses on the requirement that banks need to keep an amount of highly liquid assets (HQLA) more than the expected net outflows of funds (NCOF) within 30 days during financial distress. The expression of the credit capacity of banks with a requirement of liquidity coverage ratio can be obtained with knowledge of their cash inflows and outflows, together with some other settings (Li et al., 2017; Xiong et al., 2020).

The expressions of credit capacity and its determinants for various regulations are summarized in Table 2. The table demonstrates what variables and parameters can be the determinants of bank credit capacity. First, the establishment of banking regulations has a detrimental effect on banks' ability to extend credit. Banking regulations limit credit availability while preserving the banking system's stability. For each regulation, the credit base and credit capacity have a positive relationship, so when a shock impacts the banking system, the resulting change in credit capacity has two causes: One is the change of credit base, the other is the change in the environmental parameters, such as repayment rates and inflow ratios.

Table 2. The expressions of credit capacity for Basel III regulations.

	RR regulation	LCR regulation	LR regulation	CAR regulation
The goal of bank regulations	Control the money supply	Guard against liquidity risk from maturity mismatch	Encourage deleverage and limit balance sheet expansion	Guard against solvency risk from loan default
The requirement of bank regulations	$\frac{R}{D} \geq RR_{min}$	$\frac{HQLA}{NCOF} \geq LCR_{min}$	$\frac{E}{TA} \geq LR_{min}$	$\frac{E}{RWA} \geq CAR_{min}$
The expression of credit capacity	$L_{MAX}^{RR} = (\frac{1}{RR_{min}} + e - 1)R$	$L_{MAX}^{LCR} = \begin{cases} \left(\frac{4}{\mu \cdot LCR_{min}} + e - 1\right)R; \ IF^* \geq 0.75OF^* \\ \left[\frac{1 + 0.5\lambda(e-1)LCR_{min}}{(\mu - 0.5\lambda)LCR_{min}} + e - 1\right]R; \ IF^* < 0.75OF^* \end{cases}$	$L_{MAX}^{LR} = \left(\frac{1}{LR_{min}} - e\right)E$	$L_{MAX}^{CAR} = \frac{E}{\gamma * CAR_{min}}$
The relationship between each bank regulation and its credit capacity	$\frac{\partial L_{MAX}^{RR}}{\partial RR} < 0$	$\frac{\partial L_{MAX}^{LCR}}{\partial LCR} < 0$	$\frac{\partial L_{MAX}^{LR}}{\partial LR} < 0$	$\frac{\partial L_{MAX}^{CAR}}{\partial CAR} < 0$
The relationship between credit base and credit capacity	$\frac{\partial L_{MAX}^{RR}}{\partial R} > 0$	$\frac{\partial L_{MAX}^{LCR}}{\partial HQLA} > 0$	$\frac{\partial L_{MAX}^{LR}}{\partial E} > 0$	$\frac{\partial L_{MAX}^{CAR}}{\partial E} > 0$
The relationships between other parameters and credit capacity	$\frac{\partial e}{\partial RR} > 0$ $\frac{\partial E}{\partial RR} > 0$	$\frac{\partial \mu}{\partial LCR} < 0$ $\frac{\partial \lambda}{\partial LCR} > 0$ $\frac{\partial e}{\partial LCR} > 0$	$\frac{\partial e}{\partial LR} > 0$ $\frac{\partial R}{\partial LR} > 0$	$\frac{\partial \gamma}{\partial CAR} < 0$

Notes: The variable e is defined as E divided by R, μ denotes the run-off ratio of deposit loss to total deposits and λ denotes the proportion of repayment for each installment of the bank loan.

4. Induced transmission channels of monetary policy by bank regulations

Bank regulations impact the transmission mechanism of monetary policy via banks' credit creation. Since Basel I and Basel II were issued, the effects of bank regulations on the transmission of monetary policy have been studied. It has been argued that the presence of a bank balance sheet channel could lead to a "pro-cyclical" effect of bank capital regulation, exacerbating economic volatility by amplifying credit behavior during macroeconomic cycles (Holmstrom and Tirole, 1997; Bernanke et al.,1991). Additionally, researchers like Diamond and Rajan (2000) and Misa (2002, 2003) have shown that capital constraints may cause more serious credit contraction of banks during the economic recession, which jeopardizes financial resilience and worsens the effect of monetary stimulus. In the aftermath of the 2008 financial crisis, as Basel III was implemented, it raised the standards for bank capital requirements. More and more empirical evidence has validated that excessive leverage ratios in banking systems may amplify the susceptibility of the economy to exogenous negative shocks. However, concurrently, it has been observed that the efficacy of monetary policy in mitigating these impacts is enhanced (Cozzi et al., 2020). Furthermore, Basel III began to supervise multiform components of the balance sheets, such as unencumbered high-quality liquid assets and stable funds, by introducing various new regulations against liquidity risks. Compared to the previous unipolar regulatory framework, this signals a progressive shift towards a multipolar regulation of the financial system (Haldane, 2018).

The diverse bank regulations impose significant difficulties in fully assessing the effects of these supervising measures (Haldane, 2018). Moreover, it gets much harder to figure out all the channels of monetary policies when they are mixed with bank regulations. However, when we examine the entanglement of monetary policies and bank regulations from the standpoint of credit creation, we can identify the pass-through channels of monetary policy via banks to aggregate demand. As credit creators, banks play a crucial role in the transmission channel of monetary policy, with their credit capacity being a key variable. The purpose of bank regulations is to ensure the stability of financial systems, and as such, they impose a set of constraints on the credit expansion of banks. However, considering the motive of profit maximization, banks consider the size of their credit capacity comprehensively and determine the actual volume of credit issuance in practice. In this paper, our main focus is on examining the influence of bank regulations on credit capacity. Figure 1 depicts an overview of the induced monetary transmission under bank regulations. The monetary shock would change the balance sheet structure of banks and thus the credit capacity with different bank regulations. Following that, banks decide on the ultimate bank lending by maximizing their profits, subject to credit capacity. The transmission channels of monetary policy are induced for the reason that bank credit creation is constrained by bank regulations. Given the balance sheet of the banking system and the supervisory environment, each of the bank regulations imposed on banks will yield a credit capacity. Therefore, monetary shocks in the analysis would have impacts on banks' credit capacity and thus bank lending.

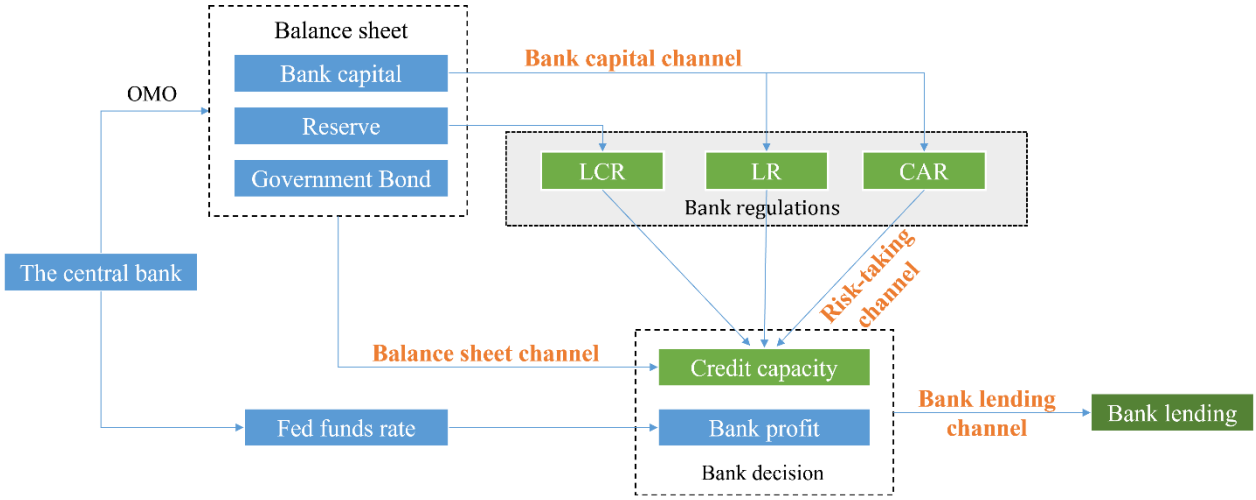

Figure 1. The transmission mechanism of monetary policy with multiple bank regulations.

We first consider the transmission channels related to changes in bank capital when monetary policy impacts banks' decisions on capital buffers. Either CAR or LR regulation builds a link between bank capital and credit capacity. As a result of the monetary shock, the level of credit capacity that corresponds to changes in capital regulations, together with the amount of bank capital, leads to an induced bank capital channel. Bank capital's buffering effect against default risk manifests itself in the following way. Bank capital is the credit base of the credit capacity of a bank, so a higher level of bank capital indicates that the bank can lend more.

When a bank's risk-taking attitude changes as a response to a monetary shock, an alternative risk-taking channel emerges as a result of the CAR regulation, which emphasizes changes in credit capacity caused by the variation in the weighted coefficients of the bank's risky assets resulting from monetary shocks. As is well known, the amount of bank capital is also closely related to the level of banks' risk-taking (Anginer et al., 2024) since adequate bank capital is an effective safeguard against shocks arising from default risk when banks face situations such as defaults and non-performing loans (Meh and Moran, 2010). The conventional channel of risk-taking is, in fact, directly linked to the bank capital. In contrast, the induced risk-taking channel highlights the role of the weighted coefficients of risky assets that are considered in the CAR regulation and thus formulate the corresponding credit capacity.

In addition to focusing on the new transmission channel of monetary policy arising from capital regulation, we are also concerned with the balance sheet channel under the impact of multiple regulations. The traditional transmission mechanism of the balance sheet channel remains unaffected when bank regulation is applied to the balance sheet. Therefore, the traditional channel's emphasis on balance sheet structure can impact how banks make their credit decisions (Jiménez et al., 2012). However, with the introduction of regulations, a new bank balance sheet channel that highlights the significance of bank balance sheet structure in determining banks' credit capacity has also emerged in the transmission of monetary policy. When a monetary shock affects the structure of a bank's balance sheet, the combined effect of multiple bank regulations creates new credit capacity, which affects the bank's decision on the volume of credit and eventual bank lending. Finally, the enactment of bank regulations also generates an induced bank lending channel, which refers to the process by which monetary shocks change the credit base of the bank in response to multiple bank regulations, thus in

turn affecting bank lending (Xiong and Wang, 2022). Table 3 specifies the channels of monetary transmission through banks under multiple regulatory constraints to provide a lucid illustration of the impact of bank regulations on the transmission mechanism of monetary policy.

Table 3. Summary of induced transmission channels of monetary policy.

The role of banks	Credit creators			
	Induced bank lending channel	Induced bank balance sheet channel	Induced bank capital channel	Induced risk-taking channel
Regulatory constraints	Multiple regulations	Multiple regulations	CAR and LR	CAR
Causality	Monetary shock → changes in the structure of balance sheet → (1) changes in bank profit; (2) changes in credit capacity → changes in bank decision →changes in bank lending.	Monetary shocks → changes in the balance sheet structure → (1) changes in bank profit; (2) Basel Accord → changes in credit capacity → changes in banks' decision →changes in bank lending.	Monetary shocks →changes in the level of bank capital → changes in credit capacity → changes in bank lending.	Monetary shocks →changes in the level of risk-weighted coefficients → changes in credit capacity → changes in bank lending.

5. The obstruction of monetary transmission

The monetary policy is a fundamental instrument in macroeconomics, utilized by central banks to ensure banking system stability and foster rapid economic growth (Smets, 2014). However, in practice, not all monetary policies may achieve their intended objectives of enhancing aggregate demand, and the procedure of monetary transmission may be impeded for some measures. For the research on the effectiveness of a monetary policy, since the money market is directly impacted by policy operations of the central bank, most have focused on the money market (Duffie and Krishnamurthy, 2016; Eisenschmidt et al., 2024). Nevertheless, there has been a growing awareness of the critical role played by the funds market in the transmission of monetary policy. Specifically, banks, being the main sector of the funds market, hold significant influence as providers of funds to the real economy. Consequently, several studies have underscored that banks possess the ability to affect the transmission effect of monetary policy by influencing the quantity of money supply (Ehrmann et al., 2003; Juurikkala et al., 2011). In this section, we will integrate the influence of bank regulations on bank lending and investigate how bank regulations affect the transmission of monetary policy through banks. Our focus is on identifying potential obstacles and disruptions that may arise in the procedure of transmission, ultimately impacting the overall effectiveness of monetary policy.

In the procedure of monetary transmission through banks, the credit capacity of banks becomes a crucial hub-link. The capacity of bank credit directly determines the effectiveness of monetary transmission. However, the credit capacity of banks is not fixed; rather, it is influenced by many factors and variables. Therefore, any factors and variables that can affect credit capacity will also impact the channel of monetary transmission. Bank regulation is one of the important factors that affect the credit capacity of banks. Recent studies have shown that overregulation after the crisis has led to a reduction

in the credit capacity of banks, thereby slowing down the recovery process of the financial system (Pyka et al., 2021). This suggests that while bank regulations help stabilize the financial system, they may also result in obstacles in the transmission of monetary policy.

Figure 2 depicts the influences of bank regulations on the monetary transmission through banks. Bank regulations can be classified into two categories: Bank capital regulations and liquidity regulations. Under a bank capital regulation, both the bank's risk-taking channel and the capital channels would work. Additionally, the bank lending channel and bank balance sheet channel are jointly influenced by both bank capital and liquidity regulations. When banks are subject to a single bank regulation, the bank's credit capacity is solely governed by the size of the corresponding credit base. Thus, ensuring the effectiveness of monetary transmission can be achieved by enlarging the effective credit base. However, when the bank's credit capacity is influenced by multiple bank regulations during the transmission process, it is necessary to identify the most restrictive constraint among these regulations. Only by increasing the credit base corresponding to the most restrictive constraint can the credit capacity be enhanced, thereby guaranteeing the effectiveness of monetary transmission.

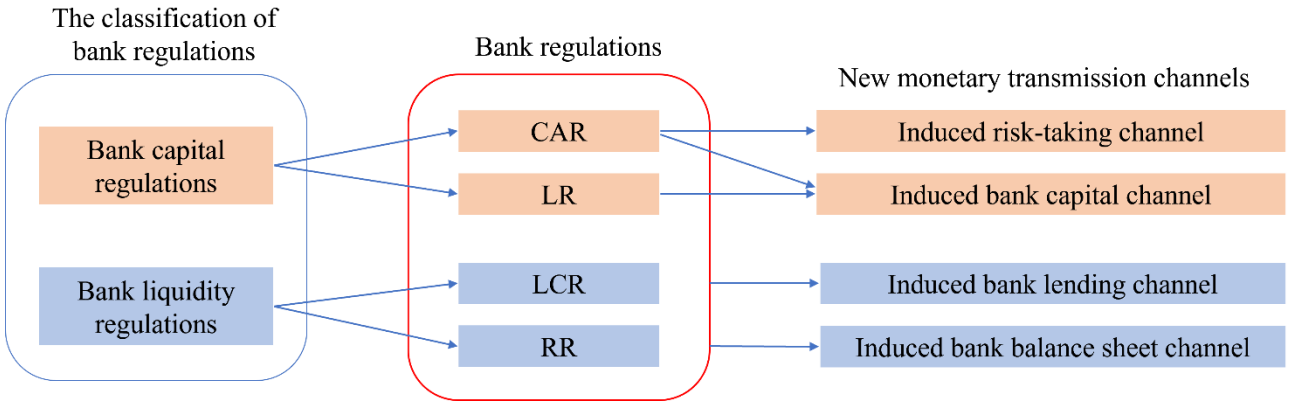

Figure 2. Monetary transmission channels with bank regulations.

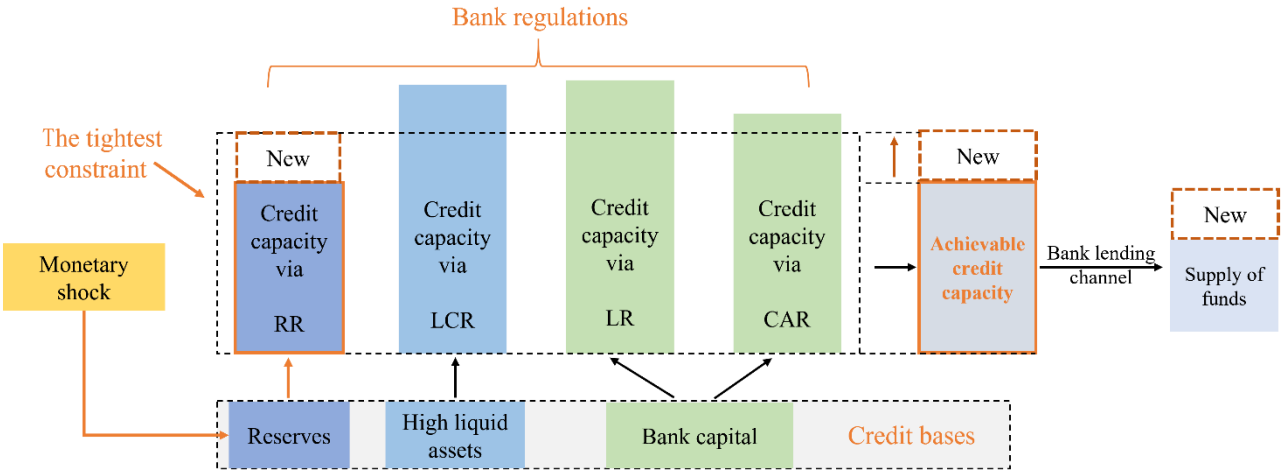

Figure 3. The obstruction of the bank lending channel with multiple regulations, as RR is the tightest constraint.

Figures 3 and 4 illustrate the examples of the bank lending channel obstruction influenced by multiple bank regulations. In the traditional transmission of the bank lending channel, banks are considered financial intermediaries that transform deposits into loans. Therefore, the prevailing method to boost the volume of loans is a monetary shock that increases bank deposits, ensuring the effectiveness of the bank lending channel. However, when we consider the impact of bank regulations on the bank lending channel from the perspective of credit creation, the credit capacity of the bank lending channel is influenced by multiple regulations, with the size depending on the tightest constraint among them. As shown in Figure 3, an increase in reserves enhances the level of credit capacity only when the required reserve ratio is the tightest constraint among multiple regulations.

The credit base of banks' credit creation with the influence of LCR regulation is high liquid assets, which also encompass reserves. However, an increase in the quantity of reserves through open market operations does not affect the credit capacity formed by the LCR regulation. This is because, while the number of reserves increases, the quantity of government bonds decreases simultaneously in the open market operation, both falling into the category of high-liquidity assets. As a result, it does not impact the credit capacity influenced by LCR regulation.

Figure 4 illustrates that when the tightest constraint regulation shifts from the required reserve ratio to capital regulations involving CAR, the corresponding credit base shifts from reserve to bank capital. In such a case, if a monetary shock aims to increase reserves and other high liquidity assets rather than bank capital, the transmission of the bank lending channel turns out to be ineffective, even encountering impediments. This explains why, after the financial crisis, despite central banks providing a large amount of liquidity to commercial banks, the expected increase in the amount of credit creation was not achieved. This is because the credit base had shifted from reserves to bank capital.

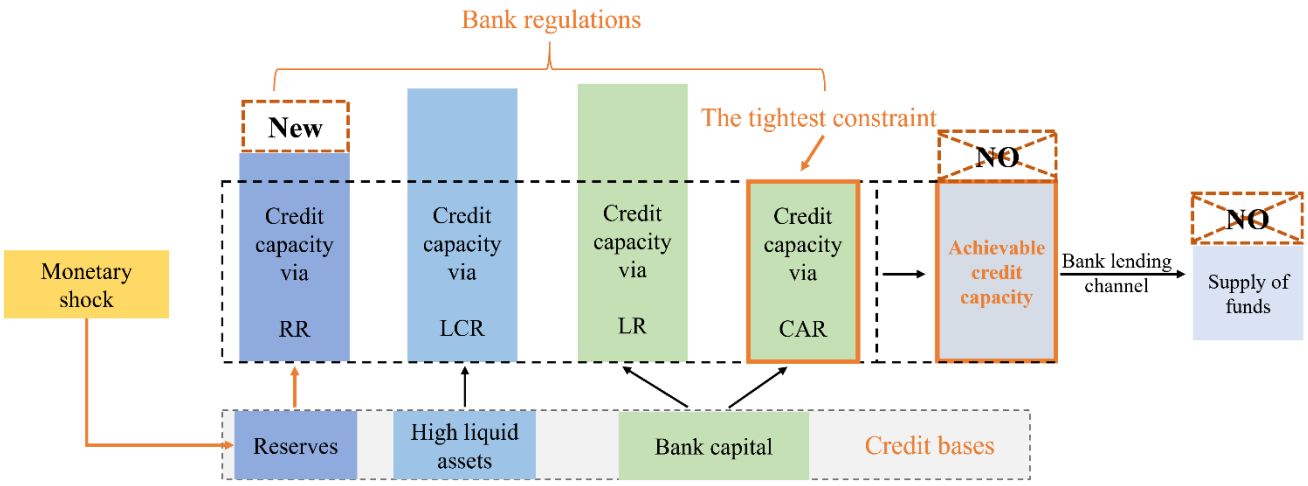

Figure 4. The obstruction of the bank lending channel with multiple regulations as CAR is the tightest constraint.

6. Empirical analysis

Through our analysis of the mechanism of monetary policy obstruction, we found that bank credit expansion was determined by the credit base associated with the tightest regulatory constraint. After the financial crisis, although central banks provided banks with unprecedented liquidity, the expected

increase in loans did not materialize. We contend that this is because the bank's credit base is bank capital rather than reserves. In this subsection, we verify it through empirical analysis.

The empirical work has proved that the enhancement of capital requirements will reduce the credit of banks and amplify the pro-cyclical effect of banks (Adrian and Shin, 2010; Imbierowicz et al., 2021). The increase of bank capital will reduce the cost of bank financing and increase bank loans (Gambacorta and Shin, 2018). Unlike previous studies that analyze the impact of bank capital on leverage and bank lending, we focus on the effect of the bank's credit base on the increase in bank loans. In our analysis, the credit base primarily consists of reserves and bank capital. Through empirical investigations, we aim to determine whether a credit base restricts bank credit expansion, and if so, which of the reserves or bank capital serves as the tightest constraint.

Accordingly, we seek to test the following hypothesis: After the financial crisis, only bank capital is positively associated with bank credit expansion.

6.1. Data and empirical methods

We utilize quarterly bank-level data from the Federal Deposit Insurance Corporation (FDIC) in the United States, covering the period from Q4 2008 to Q4 2019. These data are obtained from FDIC statistics, which provide detailed financial reports of the FDIC in a standardized format. The raw data include key financial indicators such as bank capital, loans, and reserves. This period was chosen because, after the financial crisis, there was a substantial increase in bank reserves, leading us to hypothesize that the credit base of banks has shifted to bank capital, thereby contributing to the obstruction in monetary policy transmission. In March 2020, the Federal Reserve lowered the reserve requirement for banks to zero, effectively removing reserves from the role of the tightest constraint on bank credit expansion. Consequently, we included data from 2020 onward only in our robustness checks rather than in the baseline regression analysis.

Subsequently, we performed the following data preprocessing steps:

1. Outlier Treatment: Extreme observations with absolute loan growth rates exceeding 50% were removed.
2. Exclusion of Non-Compliant Banks: Banks were flagged and removed if they failed to meet regulatory requirements (capital adequacy ratio below 5% or Tier 1 capital ratio below 3%).
3. Handling of Missing Values: Observations with missing key variable values were deleted.

We obtained an unbalanced panel dataset comprising 101605 observations. Table 4 provides the number of bank observations by quarter.

Table 4. The number of bank observations in the sample by quarter.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Q1		1790	1861	1897	1974	2231	2258	2232	2213	2216	4683	1166
Q2		1860	1912	1947	2257	2297	2277	2273	2254	4666	4752	1131
Q3		1854	1915	1946	2265	2289	2275	2254	2235	4724	1179	1123
Q4	1773	1861	1887	1941	2225	2278	2253	2224	2225	4708	1175	989

The dependent variable in this study is the loan growth rate of commercial banks. Since we are particularly interested in the impact of liquidity regulation and capital regulation on bank lending, we select the loan growth rate as the dependent variable, which is calculated as follows:

$$\mathrm{LOAN_t} = 100 * \frac{\mathrm{L_t} - \mathrm{L_{t-1}}}{\mathrm{L_{t-1}}}, \tag{6}$$

This measure captures the percentage change in a bank's loan volume over consecutive periods, allowing us to assess how regulatory constraints affect credit expansion.

Since bank regulations can be divided into two major categories, liquidity regulation and capital regulation, we selected the ratio of reserves to total assets as the credit base for bank liquidity regulation, and the ratio of bank capital to total assets as the credit base for capital regulation. The bank-specific characteristic variables include characteristics such as the natural logarithm of total assets (SIZE), the noncurrent loans ratio (NPL), the loan loss allowance ratio (ALLOW), and the proportion of non-deposit liabilities (MFUND). For the selection of control variables, we primarily refer to the work of Kim & Sohn (2017), with the specific variable definitions presented in Table 5.

Table 5. Variable definition.

The dependent variable	
$\mathrm{LOAN_t}$	Quarterly growth rate of lending (%)
The independent variable	
$\mathrm{RQ_{t-1}}$	Ratio of reserves to total assets (%)
$\mathrm{EQ_{t-1}}$	Ratio of capital to total assets (%)
The bank-specific characteristic variables	
$\mathrm{SIZE_{t-1}}$	Logarithm of total assets
$\mathrm{NPL_{t-1}}$	Noncurrent loans to loans (%)
$\mathrm{ALLOW_{t-1}}$	Loan loss allowance to loans (%)
$\mathrm{MFUND_{t-1}}$	Ratio of non-deposit liabilities to total assets (%)

First, we provide descriptive statistics for the data, as shown in Table 6. The data indicate that the mean bank loan growth rate is 1.355%, with a wide range from −49.174% to 49.983%, suggesting significant heterogeneity in bank credit behavior. The average ratio of reserves to total assets (RQ) is 3.704%, and the average ratio of capital to total assets (EQ) is 11.187%, which is consistent with the typical characteristics of the U.S. banking industry.

Table 6. Summary statistics of the variables used in the regressions.

Variable	Obs	Mean	Std. Dev.	Min	Max
LOAN	101605	1.355	4.959	−49.174	49.983
RQ	101605	3.704	5.566	0	94.727
EQ	101605	11.187	3.958	0.971	99.237
SIZE	101605	13.37	1.44	8.447	21.585
NPL	101605	1.886	2.87	0	100
ALLOW	101605	1.569	1.427	0	100
MFUND	101605	7.845	8.584	0	100

For the panel data on banks, we construct a two-way fixed effects regression model. The bank-specific characteristic variables we use include the natural logarithm of total assets, the ratio of non-deposit liabilities to total assets, the ratio of noncurrent loans to total loans, and the ratio of loan loss allowance to total loans, factors considered in the literature as important determinants of bank credit scale. All bank-specific variables are lagged by one period to mitigate any possible endogeneity bias. Therefore, the empirical model used in this study is given by:

$$\mathrm{LOAN}_{\mathrm{i,t}} = \alpha + \beta_1 \mathrm{RQ}_{\mathrm{i,t-1}} + \beta_2 \mathrm{EQ}_{\mathrm{i,t-1}} + \gamma \mathrm{Controlsit} + \eta_i + \mu_t + \varepsilon_{\mathrm{i,t}}, \quad (7)$$

where *i* denotes the bank *i*, and *t* represents the quarterly time dimension, β_1 and β_2 capture the impacts of the corresponding independent variables on bank credit supply, η_i represents the fixed effect for bank *i*, μ_t represents the fixed effect for time t, and γ denotes the effects of other bank-specific control variables on credit expansion.

6.2. Empirical results

Next, we analyze the regression results as shown in Table 7. The coefficient of the ratio of reserves to total assets (RQ) on bank loan growth is statistically insignificant, indicating that liquidity is no longer the tightest constraint on bank credit expansion after the crisis. The implementation of unconventional monetary policies, such as quantitative easing, has led to an obstruction in the transmission of monetary policy through the reserve-based adjustments. After the crisis, the capital ratio to total assets has a positive effect on loan growth, aligning with existing empirical findings on the role of bank capital. Specifically, a 1% increase in the capital ratio leads to a 0.115% increase in loan growth.

Table 7. Regression results of two-way fixed effects regression model.

	(1) LOAN	(2) LOAN
RQ	0.002	0.007
	(0.013)	(0.013)
EQ	0.193***	0.115***
	(0.042)	(0.041)
SIZE		−2.019***
		(0.246)
NPL		−0.296***
		(0.029)
ALLOW		−0.015
		(0.081)
MFUND		−0.025*
		(0.013)
_cons	−0.811	27.822***
	(0.488)	(3.374)
Observations	101605	101605
R-squared	0.207	0.225

Note: Robust standard errors, clustered at the bank and time levels, are reported in parentheses. *** p< 0.01, ** p < 0.05, * p < 0.1.

6.3. Robustness checks

To ensure the robustness of our findings, we conduct robustness checks along three dimensions: First, we extend the baseline regression by incorporating macroprudential policy variables. In addition to our original explanatory variables, we include market-level variables, GDP growth rate (△GDP), federal funds rate growth (△MP), the consumer price index (CPI), and bank market concentration (CR5), to account for macroeconomic fluctuations and changes in market structure. Market concentration refers to the market share of the loan scale of the top five largest banks. Second, we optimize the sample structure using a balanced panel data approach. By retaining only banks that operate continuously throughout the entire study period, we construct a balanced panel data set, thereby effectively controlling for sample-selection bias. Third, we extend the study window through Q4 2023. By including the most recent banking data from Q1 2020 to Q4 2023, we test the model's stability over a longer period of observation.

Table 8. Robustness Test.

	(1) LOAN	(2) LOAN	(3) LOAN
RQ	−0.008	−0.013	0.002
	(0.011)	(0.014)	(0.01)
EQ	0.168***	0.109**	0.114***
	(0.037)	(0.045)	(0.036)
SIZE	−1.032***	−1.94***	−1.753***
	(0.154)	(0.251)	(0.182)
NPL	−0.387***	−0.307***	−0.287***
	(0.029)	(0.031)	(0.027)
ALLOW	0.017	−0.03	−0.045
	(0.131)	(0.12)	(0.094)
MFUND	−0.035***	−0.013	−0.021*
	(0.012)	(0.014)	(0.012)
△GDP	−0.292***		
	(0.03)		
△MP	115		
	(0.105)		
CPI	−0.073**		
	(0.035)		
CR5	0.369***		
	(0.027)		
_cons	−1.239	27.397***	24.457***
	(2.285)	(3.483)	(2.421)
Observations	101591	80987	109793
R-squared	0.2	0.192	0.225

Note: Robust standard errors, clustered at the bank and time levels, are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As shown in Table 8, after applying these three robustness tests, the core conclusions of the baseline regression remain highly consistent: bank capital continues to exhibit a significant positive relationship with credit expansion, while the reserve ratio's effect on loan growth remains insignificant. These results confirm the reliability of our baseline estimates.

The empirical results suggest that the Basel III regulatory framework influences bank credit creation by constraining credit capacity, thereby significantly altering the monetary policy transmission mechanism. Following the crisis, capital regulation has been the tightest constraint, rendering the traditional liquidity channel ineffective. Bank capital has become the credit basis for loan expansion. Higher capital levels allow banks to expand their credit capacity within the regulatory framework. This finding provides empirical support for the "After the financial crisis, only bank capital is positively associated with bank credit expansion" hypothesis, indicating that central bank interventions via bank reserves now have a limited impact.

7. Conclusions

We investigated the transmission mechanism of monetary policy under bank regulations from the perspective of credit creation. Specifically, we introduced the concept of credit capacity first, which is defined as the maximum ability of a bank to create credit. We then examined the impacts of various regulations on credit capacity. We found that different regulations specify their credit bases and have different credit capacities, which can be expressed in terms of specific regulatory requirements, credit base, and various environmental parameters. The credit capacity of banks under multiple regulations is governed by the tightest constraint. When the monetary shock affects the credit base or parameters that characterize a bank regulation, it leads to a change in the corresponding credit capacity, and then to a change in the actual amount of loans. As a result, there is a series of induced transmission channels of monetary policy via banks.

In addition, we concentrated on how bank regulations engender these new channels. It is worthy to note that all the induced channels of monetary policy are through the credit capacity of the banking system. The capital requirement, which is represented by CAR and LR regulations, specifically formulates the new bank capital channel and the new risk-taking channel. The new bank lending channel and the new bank balance sheet channel are transmitted through the credit capacity, which is generated by the interplay of multiple regulations and the economic environment.

Finally, we explored the reasons and provided remedies for the obstruction of monetary policy based on the effect of bank regulations on credit creation. Since only the smallest credit capacity is necessary for a monetary policy to function effectively, increasing the corresponding credit base is the key to removing obstacles. After the financial crisis, the empirical results show that the credit capacity of the banking system is governed by capital regulation. However, for the balance sheets of different banks, the credit base of each bank might be different. Therefore, it is crucial to identify the most stringent regulation when there are multiple regulations and be aware that increasing the corresponding credit base would be ineffective once the credit base switches to other items.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Author Contributions

Hua Zhong: Conceptualization, Writing—original draft. Xudong Zhang: Visualization, Methodology, Writing—original draft. Yougui Wang: Review & Editing—original draft, Project administration, Supervision. All authors have read and approved the final version of the manuscript for publication.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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