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Essays on Bank Liquidity Creation

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ACADEMIC DISSERTATION

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Tiivistelmä

Tämä väitöskirja koostuu kolmesta pankkien likviditeetin luomista käsittelevästä esseestä. Ensimmäisessä esseessä tutkitaan pankkien likviditeetin luomisen ja systeemiriskin välistä yhteyttä. Tutkimustulokset osoittavat, että pankkien likviditeetin luominen lisää yksittäisten pankkien systeemistä yhteyttä finanssijärjestelmän vakaviin shokkeihin, mutta voi toisaalta samalla vähentää yksittäiseen pankkiin liittyvää systeemiriskiä.

Toisessa esseessä tarkastellaan pankkien likviditeetin luomisen ja teknologisten innovaatioiden välistä yhteyttä. Empiiriset tulokset osoittavat, että pankkien likviditeetin luominen vähentää teknologisia innovaatioita patenteilla ja patenttiviittauksilla mitattuna. Likviditeetin luominen edistää kuitenkin sellaisten yritysten innovaatioita, joilla on taseessaan keskimääräistä enemmän aineellista varallisuutta. Esseessä myös havaitaan, että pankkien likviditeetin luomisen ja teknologisten innovaatioiden välinen suhde on epäsymmetrinen.

Väitöskirjan kolmannessa esseessä selvitetään, miten erilaiset valvontakäytännöt vaikuttavat pankkien likviditeetin luomiseen. Tulokset osoittavat, että sääntelyviranomaisten valvontavallan ja likviditeetin luomisen välillä on negatiivinen yhteys. Tutkimustulokset viittaavat myös siihen, että valvontavallan ja yksityisen seurannan vaikutus on selvempi, kun tarkastellaan institutionaalisen laadun ja markkinoiden kannustimien roolia, ja nämä kaksi valvontakäytäntöä täydentävät toisiaan pankkien likviditeettiriskien vähentämisessä.

Asiasanat
Pankit, pankkitoiminta, likviditeetin luominen, systeemiriski, innovaatiot, pankkivalvonta

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Abstract

This doctoral dissertation consists of three interrelated empirical essays on bank liquidity creation which is one of the most preeminent functions of banks in the economy. In particular, each essay explores slightly different aspects of liquidity creation in financial intermediation. The first essay investigates the association between bank liquidity creation and systemic risk. The results show that bank liquidity creation increases the systemic linkage of individual banks to severe shocks in the financial system, but at the same time, it decreases the riskiness of individual banks.

The second essay examines the association between bank liquidity creation and technological innovation. The empirical findings indicate that bank liquidity creation decreases technological innovation as measured by patents and patent citations. However, liquidity creation enhances innovation by firms that have above-median asset tangibility. Further analysis reveals that the relationship between bank liquidity creation and technological innovation is asymmetric.

The third essay explores whether different supervisory practices affect banks' liquidity creation. The findings demonstrate that there is a negative association between regulators' supervisory power and liquidity creation. The empirical results also suggest that the effect of supervisory power and private monitoring is more pronounced when considering the role of institutional quality and market incentives, and these two supervisory practices are complementary mechanisms in reducing liquidity risks.

Collectively, the findings of the three essays contribute to the burgeoning literature on bank liquidity creation. In addition, the results not only provide new insights into the design of regulatory and supervisory practices of financial institutions, but also provide new evidence on different attributes of liquidity creation.

Keywords

Banking, Liquidity Creation, Systemic Risk, Innovation, Bank Regulation, Supervision, Governance

This work is dedicated to my husband,

Dr. Pezhman Mohammadi.

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Espoo, October 2021

Sara Yasar

Contents

Essays

This doctoral dissertation consists of an introductory chapter and the following three essays:

I. Davydov, D., Vähämaa, S., & Yasar, S. (2021). Bank liquidity creation and systemic risk. *Journal of Banking & Finance*, 123, 106031. [1]

II. Yasar, S. (2021). Bank liquidity creation and technological innovation. *Proceedings of the 32nd Australasian Finance & Banking Conference.*

III. Yasar, S. (2021). Bank supervision and liquidity creation. *Proceedings of the 60th Annual Meeting of the Southern Finance Association, and the 2021 International Finance and Banking Society (IFABS) Oxford Conference.*

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1 INTRODUCTION

This doctoral dissertation investigates various aspects of bank liquidity creation in three interrelated essays. Specifically, the first and second essays examine the effect of bank liquidity creation on systemic risk and technological innovation. The third essay extends the scope of the dissertation and investigates the effect of bank supervisory policies on the ability of banks to create liquidity. Overall, this thesis focuses on several hitherto unexplored questions related to liquidity creation.

According to the modern financial intermediation theory, bank liquidity creation is one of the core functions of banks in the economy. The idea that liquidity creation is the main reason for the existence of banks appears most prominently in the theoretical studies of Bryant (1980), and Diamond and Dybvig (1983). These theories suggest that banks create liquidity on their balance sheets by financing relatively illiquid assets with relatively liquid liabilities. Kashyap, Rajan, and Stein (2002) argue that banks can also create liquidity off their balance sheets through loan commitments or other kinds of claims such as standby letters of credit.

Despite the importance, liquidity creation was only a theoretical concept up until recently, and thus, it has received relatively little attention in prior empirical research. Berger and Bouwman (2009) developed the first comprehensive measure of bank liquidity creation that incorporates the contribution of all bank assets, liabilities, equity, and off-balance sheet activities. Each component of liquidity creation such as bank loans, transaction deposits, off-balance sheet derivatives, and guarantees, has different theoretically-driven weights based on ease, cost, and time for customers to obtain liquid funds from the bank. Although a number of studies in the past few years have explored the role of liquidity creation in the theory of financial intermediation, there is surprisingly little empirical evidence on the determinants and effects of bank-level liquidity creation. Thus, our knowledge is far from complete and more research needs to be done to fully understand this key economic role of banks, and its influence on financial system stability and the macroeconomy. In addition, it is of great importance to understand how supervisory policies affect one of the main economic functions of banks.

The purpose of this dissertation is to explore the role of bank liquidity creation to shed light on this crucial aspect of the financial system. Bank liquidity creation is a necessity for a well-functioning financial system. However, the process of liquidity creation reduces the liquidity of banks and exposes them to various types of risks, including liquidity crunches, and bank runs. Thus, it is of great importance to understand how liquidity creation affects the overall fragility of the banking sector and the systemic risk posed by individual financial institutions. However, no papers investigate the impact of bank liquidity creation on systemic risk, something that the first essay of this dissertation attempts to address.

Furthermore, financial intermediation has an underlying role in promoting or hampering long-term economic growth depending on the evolutionary process generating innovation (see e.g., Dosi, 1988; Fagiolo, Giachini, and Roventini, 2020). Seeking an explanation of how banks affect technological progress is a prime topic in the finance-growth nexus literature. Nevertheless, no papers yet exist which would examine the direct impact of bank liquidity creation on technological innovation. Thus, the second essay of the current dissertation aims to explore this linkage.

Additionally, financial regulation and supervision schemes have been a highly controversial issue among policymakers and scholars in the past few decades. Despite the growing literature on the role of bank regulatory and supervisory frameworks for bank stability (see e.g., Barth, Caprio, and Levine, 2004; Barth, Caprio, and Levine, 2006; Beck, Demirgüç-Kunt, and Levine, 2006; Chortareas, Girardone, and Ventouri, 2012; Barth, Caprio, and Levine, 2013; Chen, Li, Liu, and Zhou, 2020), our understanding of how bank regulation and supervision affect banks' ability to create liquidity is very scant. Hence, it is important to understand how and to what extent the empowering official supervisory authorities and private sector monitoring affect bank liquidity creation, and what are the real consequences of these two supervisory practices to financial regulators. Despite the importance, this question is understudied in the literature. The third essay of this dissertation aims to examine how these two supervisory policies affect bank liquidity creation.

This dissertation builds upon the existing evidence and expands the growing body of literature on bank liquidity creation and reveals novel evidence on different aspects of this preeminent economic function of banks. The findings also provide new and important insights into the debates on the design of regulatory and prudential policies.

The remainder of this introductory chapter is organized as follows. Section 2 describes the contribution of the whole dissertation and each essay. Section 3 provides a brief background for the essays in the dissertation. Finally, section 4 provides a summary of the essays.

2 CONTRIBUTION OF THE DISSERTATION

This dissertation contributes to the scant empirical literature on bank liquidity creation by providing new evidence on various aspects of liquidity creation in three interrelated essays. Even though the three essays are related to each other, each essay approaches the topic from a different perspective. The first essay examines the linkage between bank liquidity creation and systemic risk. In addition, this essay decomposes the systemic risk measure and explores how liquidity creation influences bank-specific tail risk and systemic linkage to severe shocks in the financial system. The second essay approaches the topic of liquidity creation from the finance-growth nexus perspective, and focuses on the fundamental role played by innovation. The third essay addresses the topic from a policy perspective, and investigates the role of strengthening supervisory power and private sector monitoring in influencing the ability of banks to create liquidity.

Collectively, this dissertation makes important contributions to the bank liquidity creation literature, as each of the three essays adds to various strands of banking literature related to the systemic risk of financial institutions, banking regulation and supervision, and technological innovation. As a whole, this dissertation unites these several streams of literature, advances understanding in various lines of inquiries in the banking literature, provides new empirical evidence, and significantly adds to the bank liquidity creation literature. A more detailed description of the contribution of each essay is provided below.

The first essay of the dissertation contributes to the existing literature in three important ways. First, the essay is the first to empirically examine the relationship between bank liquidity creation and systemic risk. Second, the essay complements and extends the work of Berger and Bouwman (2017) and Zheng, Cheung, and Cronje (2019) by decomposing systemic risk into bank-specific tail risk and systemic linkage. Third, the essay provides new evidence to suggest that aggregate liquidity creation in the system and liquidity creation at the individual bank level may have opposite effects on systemic risk, thereby further iterating the complementary roles of micro-prudential and macro-prudential supervision of the banking industry.

The second essay of the dissertation contributes to the literature in a number of ways. First, the essay fills the gap in the finance-growth nexus literature by presenting the first empirical examination of whether bank liquidity creation affects technological innovation. Second, the essay expands and complements the study of Hombert and Matray (2017) by exploring whether innovation output by firms with more tangible assets is affected by bank liquidity creation. Third, the results provide important evidence to indicate that bank liquidity creation might move the comparative advantage from innovative sectors to more tangible sectors which might not slow down short-term growth, but such shifts might stifle long-run growth as innovation generates spillovers. Therefore, knowing the efficient and optimal levels of financial resources for productive activities is crucial to ensure the effectiveness of bank liquidity creation for economic growth.

The third essay on the dissertation makes a contribution to the literature in the following ways. First, this essay examines first and foremost whether regulators' supervisory power and private sector monitoring affect bank liquidity creation. In this regard, this study contributes to the recent bank liquidity creation literature. Specifically, I complement and extend the recent findings of Berger et al. (2016) by focusing on the role of the traditional approach to bank supervision, which entails strengthening official supervisory authorities, and a supervisory strategy that empowers private monitoring of banks. Broadly consistent with the negative relation between regulatory interventions and bank liquidity creation documented by Berger et al. (2016), the findings in this paper indicate that banks operating in environments with stringent supervisory practices create lower levels of liquidity. Second, this essay shows that the quality of the institutional environment plays a crucial role in explaining the cross-country variation in bank liquidity creation. Therefore, the findings of the third essay enrich our understanding of the role of different institutional quality characteristics on the linkage between supervisory enforcement and the ability of banks to create liquidity. Third, the study shows that market incentives have an important role in monitoring banks. Thus, bank supervisors and policymakers may need to further improve private incentives to monitor banks. Finally, by examining the conditioning effects of institutional quality and market incentives, I contribute to the wider banking literature that investigates such effects on the association between bank regulatory and supervisory policies and bank stability (see e.g., Chortareas et al., 2012; Cihak, Demirgüç-Kunt, Peria, and Mohseni-Cheraghlou, 2013; Bermpei, Kalyvas, and Nguyen, 2018).

3 BACKGROUND FOR THE ESSAYS

This section briefly describes the background underlying this dissertation and each of the three essays therein. Section 3.1 presents an overview of bank liquidity creation, which is a common fundamental for all three essays. Next, section 3.2 introduces the concept of systemic risk and discusses different systemic risk measures. Section 3.3 provides a summary of the evidence on technological innovation. Finally, section 3.4 discusses different aspects of bank supervision.

3.1 Bank liquidity creation

Bank liquidity creation is one of the major roles of banks in the economy, and it can be dated back to Adam Smith (1776).[1] Bank liquidity creation, by definition, means that banks provide risky illiquid loans to customers and in return give depositors the ability to withdraw riskless liquid deposits at short notice. In other words, banks can create liquidity on their balance sheets by financing relatively illiquid assets such as long-term loans with relatively liquid liabilities such as demand deposits (Bryant, 1980; and Diamond and Dybvig, 1983), and they can also create liquidity off their balance sheets through loan commitments and other kinds of claims such as standby letters of credit (Kashyap et al., 2002). While liquidity creation is a necessity for a well-functioning financial system and a crucial ingredient for economic growth and various macroeconomic outcomes (see e.g., Dell'Ariccia, Detragiache, and Rajan, 2008; Berger and Sedunov, 2017), the process of liquidity creation inherently reduces the liquidity of banks and exposes them to different types of risks, liquidity crunches, and bank runs (see e.g., Diamond and Dybvig, 1983; Kashyap et al., 2002; Berger and Bouwman, 2009).

For a long time, liquidity creation was only a theoretical concept (see e.g., Diamond and Dybvig, 1983; Holmstrom and Tirole, 1998; Kashyap et al., 2002.), and thus it received little attention in prior empirical research. Berger and Bouwman (2009) developed a comprehensive measure of bank output that takes into account all assets, liabilities, equity, and off-balance sheet guarantees and derivatives. Each component of liquidity creation such as bank loans, transaction deposits, off-balance sheet derivatives, and guarantees, has different theoretically-driven weights based on ease, cost, and time for customers to obtain liquid funds from the bank. To summarize briefly, positive weights are given to illiquid assets, and liquid

[1] Smith (book II, chapter II, 1776) emphasizes the important role of banks in generating liquidity, and how it helped wheels of commerce in Scotland. Specifically, he states that " *the trade and industry of Scotland, however, have increased very considerably during this period, and that the banks have contributed a good deal to this increase, cannot be doubted.*".

liabilities, and negative weights are given to liquid assets, illiquid liabilities, and equity. The weights assigned to off-balance sheet activities are also similar to on-balance sheet activities. Positive weights are consistent with the theoretical notion that by creating liquidity banks actually take something illiquid from the public and in turn give the public something liquid. Negative weights are also in line with the theoretical notion that banks can destroy liquidity by financing liquid assets with illiquid liabilities or equity.

Each of the essays in the dissertation utilizes the three-step procedure of Berger and Bouwman (2009) to measure the level of liquidity creation of individual banks. In particular, the measure of liquidity creation, which incorporates all bank on-balance sheet and off-balance sheet activities, is employed. This particular procedure is outlined in Table 1.

Table 1. Construction of liquidity creation measure

Category measure		
Assets		
Illiquid assets (+1/2)	**Semiliquid assets (0)**	**Liquid assets (-1/2)**
Commercial real estate loans	Residential real estate loans	Cash and due from other institutions
Loans to finance agricultural production	Consumer loans	All securities (regardless of maturity)
Commercial and industrial loans	Loans to depository institutions	Trading assets
Other loans and lease financing receivables	Loans to state and local governments	Federal fund sold
Other real estate owned	Loans to foreign governments	
Customers' liability on bankers' acceptances		
Investment in unconsolidated subsidiaries		
Intangible assets		
Premises		
Other assets		
Liabilities and equity		
Liquid liabilities (+1/2)	**Semiliquid liabilities (0)**	**Illiquid liabilities and equity (-1/2)**
Transaction deposits	Time deposits	Bank's liabilities on banker's acceptances
Saving deposits	Other borrowed money	Subordinated debt
Overnight federal funds purchased		Other liabilities
Trading liabilities		Equity
Off-balance sheet guarantees		
Illiquid guarantees (+1/2)	**Semiliquid guarantees (0)**	**Liquid guarantees (-1/2)**
Unused commitments	Net credit derivatives	Net participations acquired
Net standby letters of credit	Net securities lent	
Commercial and similar letters of credit		
All other off-balance sheet liabilities		
Off-balance sheet derivatives		
		Liquid derivatives (-1/2)
		Interest rate derivatives
		Foreign exchange derivatives
		Equity and commodity derivatives

3.2 Systemic risk

The recent global financial crisis has highlighted the importance of interconnectivity among financial institutions that arise from the globalization of financial services. Even though such extensive interconnections may help to promote economic growth by providing smooth credit allocation, and greater risk diversification, they may also serve as a mechanism for the propagation of shocks, and spread potential disruptions across markets and borders. Indeed, the theoretical models of Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) show that financial connectedness enhances the stability of the system if the magnitude or the number of negative shocks are small. Nevertheless, beyond a certain point, such interconnections facilitate financial contagion and lead to a more fragile financial system.

The collapse of Lehman Brothers in 2008 certainly demonstrated that how and to what extent the failure of a financial institution can impose significant stress on the whole financial system and the rest of the economy. The severity of the crisis gives regulators and policymakers a wake-up call for international financial regulatory reforms to strengthen the resilience of the banking sector. Inter alia, these reforms comprised of an increase in the quality and quantity of bank regulatory capital, specifying a minimum leverage ratio, and the introduction of liquidity requirements to mitigate banks' systemic risk. Indeed, defining and quantifying the concept of systemic risk is difficult. According to the Global Financial Stability Report of the IMF (2009), systemic risk, by definition, means "a risk of disruption to financial services that is caused by an impairment of all or parts of the financial system and that has the potential to cause serious negative consequences for the real economy".

In addition, the failure of the Lehman Brothers was an example of the "too-big-to-fail" issue which created moral hazard problems and ultimately imposed system-wide costs on taxpayers. A lesson from the crisis was to address systemic risks associated with the complexity, interconnectedness, and sustainability of large financial institutions which could trigger negative externalities to the real economy. In this regard, the Basel Committee on Banking Supervision (BCBS) introduced macro-prudential regulations to impose additional requirements on Systematically Important Financial Institutions (SIFIs). Among others, introducing additional capital, and leverage ratio buffers may induce banks to better internalize up and downside risks associated with their business activities. Previous studies have acknowledged that the reforms have a positive impact on financial intermediation in the short-term and long-term. In the long-run, banks with stronger capital positions are better able to absorb shocks, while at the same time higher bank capital is associated with greater provision of credits and financial services to households and businesses (see e.g., Gambacorta and Shin, 2018; Begenau, 2020; Bahaj and Malherbe, 2020). In the short-run, the reforms for Global Systematically Important Banks (G-SIBs) help to mitigate moral hazard problems for SIFIs by significantly reducing the borrower- and loan-specific risk factors and the pricing gap for such banks, while at the same time negative effects for the real economy are constrained (Behn and Schramm, 2020).

According to the Financial Stability Board (FSB) (2011), "SIFIs are financial institutions whose distress or disorderly failure, because of their size, complexity, and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity". The identification of G-SIBs is based on twelve indicators that can be regrouped into five broad categories which are meant to capture banks' systematic importance stance through 1) size, 2) interconnectedness, 3) sustainability, 4) complexity, and 5) cross-jurisdictional activities. The list of G-SIBs is updated annually and published by the FSB each November. A recent paper by Behn, Mangiante, Parisi, and Wedow (2019) document evidence of window-dressing behavior with the objective of appearing less systematically important to the eyes of market participants, regulators, and supervisors. Specifically, they find that banks participating in the G-SIB assessments have the incentive to reduce their activities, which influence the G-SIB score, in the last quarter of each year in order to reduce the additional capital buffer requirement subjected to G-SIBs.

Indeed, while the riskiness of individual banks taken in isolation is certainly important for financial system stability, the global financial crisis revealed the importance of the collective fragility of financial institutions for the soundness of the financial system. As a consequence, many systemic risk measures have been proposed which are based on either balance sheet information or financial market data. While the accounting-based systemic risk measures are inherently backward-looking, the market-based measured are considered forward-looking assessments. A previous study by Kleinow, Moreira, Strobl, and Vähämaa (2017) compares different market-based systemic risk measures and shows that each systemic risk metric produces different estimates of systemic risk that may lead to contradicting results about the riskiness of financial institutions, therefore systemic risk assessments of financial institutions based on only one systemic risk measure should be employed cautiously.

Acharya, Pedersen, Philippon, and Richardson (2017) and Brownlees and Engle (2017) proposed marginal expected shortfall (MES) and systemic risk (SRISK). MES is defined as the expected daily decrease in the market value of equity of an individual bank when the aggregate financial sector declines below a threshold C. Formally, MES is defined as follows:

$$MES_{i,t}=E_{t-1}\left(-R_{i,t}\,|\,R_{m,t}< C\right) \tag{1}$$

To calculate Long Run Marginal Expected Shortfall (LRMES), the estimated MES can be extrapolated to a market downturn with a severe market drop that lasts for a longer period. Following Acharya, Engle, and Richardson (2012), LRMES can be defined as follows:

$$LRMES_{i,t}=1-\exp(-18\times MES_{i,t}) \tag{2}$$

Acharya et al. (2012) extend the MES by considering the liabilities and the size of individual financial institutions. The SRISK is defined as the expected capital shortage of a bank amidst a financial crisis computed based on MES and the bank's capital structure under the assumption that a bank needs at least eight percent of equity capital relative to its total assets. In this regard, a bank with the highest capital shortfall is the one that contributes the most to the crisis, and such a bank is considered as most systematically risky. Formally, SRISK can be defined as:

$$SRISK_{i,t}=k\left(Debt_{i,t}\right) - (1-k)\left(1 - LRMES_{i,t}\right) Equity_{i,t} \tag{3}$$

Where k is the capital ratio which is set to be 8%, Debt is the market value of debt, and Equity is the market value of equity. The SRISK also considers the interconnectedness of a bank with the rest of the financial system through LRMES.

Van Oordt and Zhou (2019) developed a novel systemic risk measure to gauge the contributions of individual banks to systemic risk. The key advantage of this market-based approach is that it enables us to decompose the systemic risk of individual banks into bank-specific tail risk and systemic linkage to severe shocks in the financial system. This decomposition is important for two reasons. First, from the macro-prudential supervision perspective, for banks with the same level of standalone risk, those banks that are more sensitive to systemic shocks are systemically riskier. Second, from the micro-prudential perspective, for banks with the same sensitivity to severe shocks in the financial system, those banks that have a higher level of tail risk are more systemically risky. This systemic risk measure can be formally expressed as:

$$\log(\beta_i^T)=\log \tau_i \left(\frac{n}{T}\right)^{\frac{1}{\xi_m}} +\log \frac{VaR_i(n/T)}{VaR_m(n/T)} \tag{4}$$

$$\log(\text{Systemic risk}) = \log(\text{Systemic linkage}) + \log(\text{Tail risk}) \tag{5}$$

Where the market tail index ξ_m is estimated following Hill (1975), VaR is estimated from the lowest n daily bank stock and market returns, $\tau_i(n/T)$is estimated non-parametrically following Embrechts, De Haan and Huang (2000), and T is the number of daily return observations in the estimation window.

As can be noted from Equation (4), the systemic risk of individual banks β_i^T consists of two components. The first component $\tau_i(n/T)^{1/\xi_m}$ measures the systemic linkage of individual banks to severe shocks in the financial system. This component can be interpreted as the proportion of bank i's tail risk that is associated with extreme market shocks. The second component $\frac{VaR_i(n/T)}{VaR_m(n/T)}$ measures the level of bank-specific tail risk. This component is simply the ratio between VaR of bank i and VaR of the aggregate financial sector; the higher the ratio, the higher the tail risk of bank i relative to the index of financial institutions.

Another measure that is widely used in the systemic risk literature is conditional value-at-risk (ΔCoVar) proposed by Adrian and Brunnermeier (2016). This particular systemic risk indicator measures the value-at-risk (VaR) of the financial institutions conditional on other financial institutions being in distress. While the VaR of two financial institutions might be the same in isolation, the contribution of each financial institution to systemic risk is different substantially. As discussed by Adrian and Brunnermeier (2016), ΔCoVar captures the tail-dependency between a particular financial institution and the financial system as a whole.

Recall that the Var of a financial institution is defined as:

$$Pr\left(X^i \leq Var^i\right) = q \qquad (6)$$

Where X^i is the loss of financial institution i for the specified Var^i.

Adrian and Brunnermeier (2016) define $CoVar^{j|i}$ as the VaR of institution j conditional on some event $C(X^i)$ of institution i:

$$Pr\left(X^j \leq CoVar^{j|i} \middle| C(X^i)\right) = q \qquad (7)$$

Given CoVar, the ΔCoVaR is defined as follows:

$$\Delta CoVar^{j|i} = CoVar^{j|X_i=VaR_i} - CoVar^{j|X_i=median(X_i)} \qquad (8)$$

ΔCoVar can be estimated using quantile regressions, but Adrian and Brunnermeier (2016) also show that it can be computed using other techniques such as GARCH models.

3.3 Technological innovation

According to the Oslo Manual of the Organization for Economic Co-operation and Development (OECD) in 1997, technological innovation, by definition, refers to "the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these.".

While technological innovation is characterized by asymmetrical information, moral hazard problems, long-run monitoring, and commitment of capital (Hall, 2002; Akerlof, 1970), it is a source of competitive advantage for firms (Porter, 1992). Holmstrom (1989) argues that innovation requires risky, long-term, and idiosyncratic investment in intangible assets that involves companies in the exploration of unknown approaches. On the one hand, intangible assets tend to be more difficult to price, and hard to verify. Such assets also have low redeployability, and higher uncertainty in liquidation value. As such, intangible assets might tend to represent poor collateral and increase intermediation frictions (see e.g., Williamson, 1988; Shleifer and Vishny, 1992). On the other hand, market frictions create incentives for the emergence of financial intermediaries. Banks can ameliorate information asymmetry and transaction costs, and thus they influence saving rates, investment decisions, technological innovation, and ultimately long-run growth rate. This shows the importance of financial intermediaries in the economy.

Schumpeter (1911) introduced the idea that technological innovation is the main driver of economic growth. Since then, many researchers have tried to develop a model showing that financial intermediaries can facilitate technological innovation in the economy. For example, the theoretical models of King and Levine (1993b) and Laeven, Levine, and Michalopoulos (2015) develop Schumpeter's view and show that financial intermediaries play an essential role in promoting and facilitating technological innovations in the economic system. On the contrary, the theoretical model of Aghion and Tirole (1994) suggests that the moral hazard problem and asymmetric information are key impediments to corporate innovation because outcomes of innovative projects are unpredictable and difficult to contract ex-ante. In addition, Zingales and Rajan (2003) argue that bank financing may discourage firms from investing in innovative projects under relationship lending because novel projects involve large ex-ante uncertainty that is not desirable for banks to collect information. Collectively, theories provide conflicting views on the role of financial intermediaries in technological innovation.

In addition to contradictory theoretical predictions, the empirical studies offer conflicting predictions about the role of the financial system in promoting or hampering innovation. For instance, Amore, Schneider, and Žaldokas (2013) find that interstate banking deregulations foster corporate innovation. On the other hand, Cornaggia, Mao, Tian, and Wolfe (2015) exploit interstate banking deregulation to test the effect of banking competition on technological innovation and find that banking competition has a negative impact on innovation by public firms. Another strand of the literature shows that relationship-based bank financing and bank interventions are negatively associated with innovation output (see e.g., Atanassov, Nanda, and Seru, 2007; Gu, Mao, and Tian, 2017). Hsu, Tian, and Xu (2014) provide cross-country evidence suggesting that credit market development has a negative effect on industries' innovation. Most recently, Xin, Sun, Zhang, and Liu (2019) also find that debt financing decreases radical innovation in China.

In general, despite the growing literature on the role of financial intermediaries in technological innovation, there is no evidence yet on the direct impact of bank liquidity creation on technological innovation. Therefore, the second essay of the dissertation examines how banks affect technological progress by focusing on the role of bank liquidity creation. In other words, I advance the line of inquiry in the innovation literature as to how financial intermediaries affect innovation by using a comprehensive measure of bank output in the economy.

In the past few years, corporate innovation has attracted considerable attention among scholars. Specifically, a growing body of literature on innovation is emerging that investigates the determinants of technological innovation, measured by patent-based metrics. For example, prior studies examine how corruption, stock market liberalization, bank competition, banking deregulation, debt financing, and stock liquidity affect innovation (see e.g., Chava, Oettl, Subramanian, and Subramanian, 2013; Fang, Tian, and Tic, 2014; Cornaggia et al., 2015; Xin et al., 2019; Ellis, Smith, and White, 2020; Moshirian, Tian, Zhang, and Zhang, 2020).

In the innovation literature, technological innovation is measured by the number of patent applications a firm files in a year that are eventually granted. Patents are not only quantified measurements of technological innovation, but they are also a function of innovation input. In addition, patent activities capture how effectively a company has utilized both its observable and unobservable input.[2] Although a company's number of patent applications is straightforward to calculate, this measure cannot distinguish groundbreaking innovations from incremental technological discoveries (Trajtenberg, 1990). Therefore, a second measure of company innovation productivity is employed in the literature, namely the number of citations. In particular, the citation count each patent receives in the subsequent

[2] R&D expenditure can be considered as observable input, and thus it fails to capture the quality of innovation.

years is used as a second measure of innovation output. While the number of citations captures the economic importance of innovation output, the number of patents captures the quantity of innovation output.

The existing literature suggests that there is a truncation bias observed in the two measures of innovation output. The first truncation bias arises as patents appear in the database only after they are granted. Therefore, there is a gradual decrease in the number of patents as one approaches the last few years in the sample period. This is because there is usually a two-year lag between a patent's application year and a patent's grant year. The second truncation bias is related to the citations as patents keep receiving citations over a long period. The truncation bias observed in the two measures of innovation output is corrected by employing the "quasi-structural" approach or the "fixed effect" approach proposed by Hall, Jaffe, and Trajtenberg (2001). To explain "quasi-structural" briefly, truncation bias for the number of patents can be corrected by calculating the application-grant lag distribution, and then the truncation-adjusted patent is calculated using the patent truncation correction factor estimated from application lag distribution. Each patent citation is also corrected using the citation truncation weight factor estimated from the citation-lag distribution. The truncation bias for the number of patents and patent citations can also be corrected using the "fixed effect" approach by scaling each patent or citation count by the average number of patents or citations of all firms in the same year and technology class.

3.4 Bank supervision

The banking sector is one of the most regulated sectors in the world. Due to significant developments in the global financial markets, it is important to promote effective and sound banking supervision in all countries around the world. Weakness in the banking system can jeopardize financial system stability, and put the whole economy at a halt. Thus, the implementation of sound and effective banking supervision is the first step towards promoting financial system stability. The recent global financial crisis that commenced in 2007 provides strong evidence of the need for bank regulation and supervision reforms. Specifically, the reforms provide a solid basis for a resilient banking sector that helps to prevent the build-up of systemic risk and allows the banking sector to support the real economy throughout different economic cycles.

Because of Basel III's extensive regulatory reforms undertaken in the past decade, banks were more resilient at the beginning of the Covid-19 crisis in terms of capital and liquidity positions comparing to the previous crisis. In addition, in response to the Covid-19 crisis, supervisory authorities acted swiftly and announced a series of measures to help banks to withstand shocks while providing credits and financial services to households and companies through this peculiar crisis. Unlike the last financial crisis where banks were the elements of spreading shocks into the real economy, during the Covid-19 crisis banks try to be part of a solution and not the origins of problems by supporting the macroeconomic stimulus.

Supervisory authorities are responsible for the enforcement of bank regulations and examining banks to ensure their safety and soundness. Indeed, according to Basel II's second pillar, official supervisory power constitutes a crucial component of a supervisory review process together with restrictions on banking activities and disciplinary actions where law breaches are revealed. Among other principles for having an effective banking supervision system, supervisory authorities need to regularly monitor banks and assess the quality of a bank's internal corporate governance policies and the reliability of disclosed information by banks. Official supervisors might be better positioned to inspect banks because banking monitoring is costly, time-consuming, and difficult.

Nonetheless, there are conflicting and inconclusive views on the role of official supervisory power in the banking literature. According to the "supervisory power view", powerful supervisory authorities can act in the best interests of society and maximize society's welfare. In such a situation, they directly discipline and monitor non-compliant banks and can reduce market failure and overcome market imperfections. In contrast, according to the "regulatory capture view", powerful supervisory authorities may abuse their power and exert their own private benefits rather than social welfare maximization (Shleifer and Vishny, 1998; Djankov, La Porta, Lopez-de-Silanes, and Shleifer., 2002; Barth et al., 2004; and Barth et al., 2006).

In addition to official supervisory authorities, private investors can contribute to an effective and sound banking environment through public disclosure of accurate information (Basel II's third pillar). However, no consensus exists on whether official supervision has an advantage over the private sector in monitoring banks. According to the "private empowerment view", supervisory authorities may not have an incentive to ease market failure because regulators and supervisors do not have an ownership stake in the banks, and thereby they have different incentives than private creditors for monitoring and disciplining banks. Therefore, encouraging private monitoring and market discipline may promote a better functioning banking system. On the contrary, private monitoring might be difficult in a complex and opaque banking sector. For example, Chortareas et al. (2012) find that private sector monitoring can lead to higher bank inefficiency. Therefore, it is important to ensure that investors fully understand and fairly price the risks involved in banking activities.

Due to these opposing views on supervisory power and market-based monitoring, an empirical study is crucial to inform policy decisions about the real consequences of empowering official supervisory authorities, and private sector monitoring to financial regulators.

Previous studies have also acknowledged that the effectiveness of bank regulation and supervision can depend on the quality of institutional characteristics. For example, using a sample of commercial banks from 69 countries, Bermpei et al. (2018) show that the negative effect of official supervisory power on bank stability weakens at a higher level of control of corruption. Also, Chortareas et al. (2012) document that the beneficial effects of official supervisory power on bank efficiency are more pronounced with a higher quality of the institutional environment. However, no empirical paper yet exists that would investigate the role of the quality of institutional characteristics on the relationship between bank supervisory practices and liquidity creation. This is something that the third essay of this dissertation attempts to address.

Indeed, the bare existence of regulatory or supervisory practices does not necessarily mean its application in practice. Given that the institutional quality can enhance or impede the implementation of supervisory practices, it is important to identify sources of heterogeneity when looking into different regulatory and supervisory policies.

In addition, disclosing information about banks does not necessarily imply greater private sector monitoring unless market participants have incentives to use the published information to monitor banks. The prevalence of deposit insurance and government interventions in the banking sector may undermine the incentives of market participants to monitor banks. Taken together, a lack of incentives of market participants may diminish the beneficial effect of supervisory monitoring.

A prior study by Cihak et al. (2013) shows that countries that have weaker market incentives for private sectors to monitor banks had a lower crisis probability. Their evidence suggests that there is room for improving private incentives to monitor banks. Also, Anginer, Bertay, Cull, Demirgüç-Kunt, and Mare (2019) document that more countries have introduced a deposit insurance scheme, and in some instances, these schemes are more generous than before the crisis, which may lead to diminishing monitoring incentives of depositors. The introduction and the generosity of deposit insurance schemes may help to maintain confidence in the banking sector. However, these expansions are more likely to come at a cost concerning market discipline. Overreaction to restore public confidence in the banking sector in the short-run can have a destabilizing impact over a longer period. A section in the third essay of this dissertation is related to this strand of literature and examines the role of market incentives on the association between bank supervisory practices and liquidity creation.

One of the essential roles of banks in the economy is liquidity transformation which involves banks transforming short-term deposits into long-term loans. However, this preeminent role of banks makes them vulnerable to liquidity risk. The recent financial crisis underscores the importance of bank liquidity management, which is an important ingredient for better functioning of the financial markets as well as the banking sector. Liquidity, by definition, means “the ability of a bank to fund increases in assets and meet obligations as they come due, without incurring unacceptable losses”(BIS, 2008).

In the aftermath of the global financial crisis, the Basel Committee on Banking Supervision documented “that many banks had failed to take account of a number of basic principles of liquidity risk management when liquidity was plentiful” (BIS, 2008). As a result, the central banks had to intervene and provide an unprecedented level of liquidity to support the financial system, and even with such extensive support, many banks failed. The 2007-2008 global financial crisis showed how fast and severely illiquidity can crystallize and some particular sources of funding can evaporate (BIS, 2009).

A main characteristic of the crisis was how liquidity risk was managed in an inaccurate and ineffective way. In recognition for banks to address their liquidity management deficiencies, the Basel Committee on Banking Supervision introduced a global framework to strengthen liquidity risk management (BIS, 2009). Among other regulatory standards for elevating the resilience of the financial system, the Basel III accords issued a proposal for the implementation of the Net Stable Funding Ratio (NSFR). NSFR is the ratio of the available amount of stable funding to the required amount of stable funding. Specifically, this ratio is proposed to promote the long-term resilience of banks by requiring banks to fund their activities with more stable funding sources.

Prior studies argue that liquidity creation increases banks’ exposure to liquidity risk (see e.g., Allen and Santomero, 1998; Allen and Gale, 2004). Given that higher values of liquidity creation show higher bank illiquidity (i.e. higher liquidity risk), a section in the third essay of this dissertation investigates the effect of bank supervision on bank liquidity risk using two proxies for liquidity risk measures. Specifically, the essay explores the direct and combined impact of the effectiveness of two supervisory practices on bank liquidity requirements as measured by the inverse of the net stable funding ratio and the liquidity transformation ratio. For consistency with the liquidity creation measure, the inverse of this regulatory ratio is calculated, with higher values corresponding to higher illiquidity. The inverse of this regulatory ratio is the ratio of the required amount of stable funding to the available amount of stable funding. The compositions of assets and liabilities to calculate the net stable funding ratio according to Basel III accords (BIS, 2009) are outlined in Appendix 1. The liquidity transformation ratio (LTR), which is defined as the ratio of illiquid assets to illiquid liabilities following Deep and Schaefer (2004), is utilized as another proxy for bank liquidity risk.

4 SUMMARY OF THE ESSAYS

This dissertation includes three essays. The contribution of each co-author of essays is outlined below:

Essay 1: Sara Yasar was responsible for the research idea, data collection, empirical analysis, writing the first draft. Professor Sami Vähämaa contributed to this paper by writing and re-writing some parts of the paper, and giving valuable comments and suggestions for improving the paper. Professor Sami Vähämaa also supervised the publication process. Dr. Denis Davydov contributed to this paper by writing and re-writing some parts of the paper, participating in empirical analysis, and giving suggestions for improvement. A detailed authorship contribution statement is included in the published version of the paper.

Essay 2: The essay is single-authored by Sara Yasar.

Essay 3: The essay is single-authored by Sara Yasar.

4.1 Bank liquidity creation and systemic risk

The first essay of the dissertation examines the linkage between bank liquidity creation and systemic risk. While liquidity creation is a necessity for a well-functioning financial system and a crucial ingredient for economic growth and various macroeconomic outcomes (see e.g., Dell'Ariccia et all., 2008; Berger and Sedunov, 2017), the process of liquidity creation inherently reduces the liquidity of banks and exposes them to different types of risks, liquidity crunches, and bank runs (see e.g., Diamond and Dybvig, 1983; Kashyap et al., 2002; Berger and Bouwman, 2009). Given that prior studies have acknowledged that bank liquidity creation may not only affect the fragility of individual financial institutions but may also have severe negative externalities to overall financial stability (see e.g., Acharya and Naqvi, 2012; Fungacova, Turk and Weill, 2015; Acharya and Thakor, 2016; Berger and Bouwman, 2017; Zheng et al., 2019), it is of great importance to investigate how liquidity creation affects the overall fragility of the banking sector and the systemic risk posed by individual financial institutions.

The empirical analysis is performed using quarterly data on U.S. bank holding companies from 2003 to 2016. In this study, a novel systemic risk measure developed by Van Oordt and Zhou (2019) is employed. Specifically, this market-based systemic risk measure enables us to decompose the systemic risk of individual banks into bank-specific tail risk and systemic linkage to severe shocks in the financial system. In addition, two other systemic risk measures are used as alternative metrics, namely marginal expected shortfall (MES) and systemic risk (SRISK) proposed by Acharya et al. (2012) and Brownlees and Engle (2017). The three-step procedure of Berger and Bouwman (2009) is utilized to measure the level of liquidity creation of individual banks. In particular, we use the measure of liquidity creation which incorporates all bank on-balance sheet and off-balance sheet activities as well as four alternative measures that distinguish between liquidity creation on the asset and liability sides of the balance sheet and between the on-balance sheet and off-balance sheet activities.

The empirical results reported in this essay indicate that liquidity creation decreases the systemic risk contribution of individual banks after controlling for bank size, funding and income structure, asset risk, and other bank-specific attributes. After decomposing systemic risk into bank-specific tail risk and systemic linkage, it is shown that the riskiness of individual banks is strongly negatively linked to liquidity creation, while the systemic linkage of individual banks to severe shocks in the financial system is positively associated with bank liquidity creation.

The findings of this essay also suggest that banks that create low levels of liquidity are associated with higher systemic risk and higher bank-specific tail risk than other banks. On the other hand, the systemic risk of banks that create high levels of liquidity and also their stand-alone tail risk is lower compared to other banks. Further analysis reveals that the observed negative linkage between liquidity creation and systemic risk is more pertained to banks with lower deposits-to-assets ratios and the weakest capital buffers.

Collectively, the empirical findings demonstrate that the level of bank liquidity creation may have important implications for financial stability and micro- as well as macro-prudential supervision and regulation of financial institutions.

4.2 Bank liquidity creation and technological innovation

The second essay of the dissertation investigates how banks affect technological progress by focusing on the role of bank liquidity creation. On the one hand, the focus on technological innovation is reinforced by the fact that innovation is the main channel through which financial function may affect economic growth because innovation can lead to higher productivity (Solow, 1957). In addition to long-run economic growth, corporate innovation is a source of competitive advantage for firms (Porter, 1992). On the other hand, liquidity creation is a core economic function of banks and it can be dated back to Adam Smith (1776). Bank liquidity creation is a comprehensive measure of bank total output in the economy which includes assets, liabilities, equity, and bank's off-balance sheet activities. Even though previous research has revealed that bank liquidity creation is positively related to economic growth (see e.g., Fidrmuc, Fungacova, and Weil, 2015; Berger and Sedunov, 2017), a linkage between bank liquidity creation and innovation, which is the main channel through which GDP growth is affected, is missing in the literature. This paper is the first study to examine this linkage.

Previous theoretical and empirical studies have contrasting views on the role of the financial system in technological innovation. For instance, Amore et al. (2013) find that interstate banking deregulations foster corporate innovation. On the other hand, Cornaggia, Mao, Tian, and Wolfe (2015) exploit interstate banking deregulation to test the effect of banking competition on technological innovation and find that banking competition has a negative impact on innovation by public firms. In addition, Hsu, Tian, and Xu (2014) provide cross-country evidence suggesting that credit market development has a negative effect on industries' innovation. More recently, Xin, Sun, Zhang, and Liu (2019) also find that debt financing decreases radical innovation in China. I advance this line of inquiry as to how financial intermediaries affect innovation by using a comprehensive measure of bank output in the economy. Thus, a key difference between the current study and the previous literature is that I focus on bank liquidity creation as one of the most important economic roles of banks. A vast majority of empirical studies use bank credit which only considers a part of banks' function, and it cannot reflect the total bank output in the economy.[3] Banks' off-balance sheet activities account for about fifty percent of all liquidity creation in the US (Berger and Bouwman, 2009), and thus neglecting off-balance sheet activities may fail to capture a major part of bank output. For example, off-balance sheet guarantees, and derivatives allow firms to expand their investment and capital expenditure without facing significant price risks.

The empirical analysis is performed using the National Bureau of Economic Research (NBER) Patent and Citation database created by Hall et al. (2001) for the period 1984-2006.[4] This database provides the annual information on patent assignee names, the number of patents, the number of citations for each patent, a patent's application year, a patent's grant year, etc. In this study, the main variable of interest is state-level liquidity creation normalized by the state's total gross

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[3] Some papers have used branch density or the ratio of liquid liabilities to GDP as a measure of financial development (see e.g., King and Levine 1997a; Benfratello, Schiantarelli, and Sembenelli, 2008). However, liquid liabilities may not reflect the total bank output, and are also part of liquidity creation measure.

[4] A vast majority of studies in the existing innovation literature use the NBER Patent and Citation database (see e.g., Hirshleifer, Low, and Teoh, 2012; Amore et al., 2013; He and Tian, 2013; Hirshleifer, Hsu, and Li, 2013; Bena and Li, 2014; Fang et al., 2014; Chang, Fu, Low, and Zhang, 2015; Acharya and Xu, 2017; Cornaggia et al., 2015; Hombert and Matray, 2017; Nguyen, 2018; Entezarkheir, 2019).

assets held by banks (Berger and Bouwman, 2009). Overall, the sample consists of annual state-level observations on the US commercial banks and firms' patent and patent citations between 1984 and 2006.

The empirical results reported in this essay show that although bank liquidity creation adversely affects firms' innovation on average, this effect mainly comes from the group of firms with below-median asset tangibility. Taken together, these results indicate that bank liquidity creation might move the comparative advantage from innovative sectors to more tangible sectors. Reshaping comparative advantages from innovative sectors to more tangible sectors may not slow down short-term growth. However, this shift might stifle long-run growth as innovation generates spillovers.

In addition, the state-industry-level results suggest that the observed negative relation between bank liquidity creation and technological innovation is mainly driven by the finance industry. Further evidence reveals that the relationship between bank liquidity creation and technological innovation is asymmetric. In light of the findings, this essay expands the existing literature and stresses the fundamental role played by innovation in the finance-growth nexus.

4.3 Bank supervision and liquidity creation

The third essay of the dissertation examines whether regulators' supervisory power and private sector monitoring of banks affect banks' liquidity creation. Specifically, this essay attempts to explore what are the real consequences of empowering official supervisory authorities and private sector monitoring to financial regulators. Despite significant interest in the global regulatory frameworks, this question is understudied in the literature. The purpose of the third essay is to provide a comprehensive analysis of how and to what extent these two supervisory policies affect bank liquidity creation. In doing so, the essay utilizes the World Bank survey data on bank supervisory practices together with a sample of publicly traded banks in 27 European countries, and aims to test different conjectures.

The analysis in the essay is motivated by previous theoretical and empirical work. From a theoretical perspective, Mailath and Mester (1994) show that the regulator's policy influences the risk-taking behavior of banks. In the absence of effective and sound supervision, the likelihood of bank distress and bank runs increases when illiquid assets are financed with liquid liabilities (see e.g., Diamond and Dybvig, 1983; Allen and Gale, 2004). From an empirical perspective, a recent study by Berger et. al (2016) finds that regulatory interventions reduce bank liquidity creation using a supervisory German dataset. Using a sample of commercial banks in

27 European countries, I advance this line of inquiry by focusing on the role of two supervisory systems (i.e. official supervisory power and private sector monitoring) in enhancing or impeding the ability of banks to create liquidity.

The studied sample consists of 220 commercial banks in Europe over the period 1996-2013. Data on official supervisory power and private sector monitoring is obtained from the World Bank's Bank Regulation and Supervision Survey, which was conducted in 1999, 2003, 2007, and 2011. In particular, this study uses the Official Supervisory Power Index (OSPI). This index is a measure of the strength of bank supervision, indicating whether the supervisory authorities have the authority to take specific actions to overcome market failures and prevent and correct problems. Also, the essay utilizes the Private Monitoring Index (PMI). In particular, this index measures the degree to which regulatory and supervisory practices require accurate and reliable information disclosure. In this study, bank liquidity creation is calculated based on the three-step procedure of Berger and Bouwman (2009) using balance sheet data obtained from Bloomberg.

The findings of the third essay indicate that powerful supervisors, who regularly monitor banks and adopt a more forceful enforcement perspective, tend to decrease bank liquidity creation. However, the evidence shows that empowering private sector monitoring is not related to liquidity creation. This essay also tries to identify the underlying economic channel by examining how the impact of regulators' supervisory power and private sector monitoring varies across the institutional quality characteristics of individual countries. The empirical findings suggest that the negative effect of supervisory power on liquidity creation weakens at higher levels of the quality of country-level governance. In addition, the results show that the effect of private sector monitoring on liquidity creation strengthens at higher levels of the quality of nation-wide governance. Further evidence also reveals that the effect of private sector monitoring on liquidity creation is more pronounced when there are weaker incentives for the private sector to monitor banks.

Given that higher values of liquidity creation indicate a bank's higher exposure to liquidity risk (see e.g., Allen and Santomero, 1998; Allen and Gale, 2004), this study ends the analysis by validating the association between bank supervisory policies and bank illiquidity. In particular, the direct and combined impact of the effectiveness of the two supervisory practices on liquidity risk is examined. To calculate the liquidity risk, two measures are employed in the study. First, for consistency with the liquidity creation measure, the inverse of the net stable funding ratio proposed by the Basel Committee on Banking Regulation and Supervision (BIS, 2009) is used. Second, the liquidity transformation ratio proposed by Deep and Schaefer (2004) is utilized as a proxy for bank liquidity risk. The results show that there is a complementary and amplifying combined effect of the two supervisory practices on bank liquidity risk. Overall, the findings indicate that supervisory power and private monitoring affect bank liquidity creation by mitigating liquidity risk.

Collectively, the analysis shows that institutional quality characteristics condition the effect of bank supervision on liquidity creation. As such, it is important to identify differences in the stringency of law enforcement and institutional quality attributes that could enhance or impede regulatory and supervisory implementation capacity. The evidence may suggest that putting all banks under common regulatory and supervisory practices is difficult, as banks operating in certain environments may expose to higher risks. Moreover, policymakers and supervisory authorities may need to pay closer attention to the interplay between various regulatory and supervisory policies, rather than attempting to identify the separate impact of different supervisory frameworks on bank liquidity. Last but not least, given that the presence of a deposit insurance scheme and greater power and responsibility for the deposit insurer to intervene in the banking sector to rescue ailing banks can undermine incentives of market participants to monitor banks, authorities may need to improve market incentives and increase the pool of market participants that have an interest in monitoring banks.

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Appendix

Appendix 1. Calculation of the net stable funding ratio

Assets	Corresponding definition of BIS	Weights
Required amount of stable funding		
Cash and near cash items	Cash	0
Interbank assets	Loans to financial entities having effective maturities of less than one year	0
Marketable securities and other short-term investments	Securities with effective remaining maturities of less than one year	0
Commercial loans	All other assets	1
Consumer loans	Loans to retail clients having residual maturity of less than one year.	0.85
Other loans	All other assets	1
Long-term investments	Unencumbered listed equity securities or unencumbered corporate bonds rated at least A- with an effective maturity of greater than 1 year)	0.5
Fixed assets	All other assets	1
Other assets	All other assets	1
Customer acceptances	Unencumbered listed equity or nonfinancial senior unsecured corporate bonds rated at least A- (with remaining maturity > 1 yr)	0.5
Liabilities	Corresponding definition of BIS	Weights
Available amount of stable funding		
Demand deposits	Retail deposits and/or term retail deposits with residual maturities of less than one year	0.7
Saving deposits		0.7
Time deposits	Other liabilities with effective maturities of one year or greater	1
Other term deposits	Other liabilities with effective maturities of one year or greater	1
Short-term borrowings	All other liabilities and equity categories not included in the above categories	0
Other short-term liabilities	All other liabilities and equity categories not included in the above categories	0
Long-term borrowings	Other liabilities with effective maturities of one year or greater	1
Other long-term liabilities	Other liabilities with effective maturities of one year or greater	1
Subordinated debentures	Total amount of capital, including both Tier 1 and Tier 2, and total amount of any preferred stock not included in Tier 2 that has an effective maturity of one year or greater	1
Preferred equity		1
Minority interests		1
Shareholder common capital		1
Retained earnings		1

This table presents the balance sheet weights used to calculate the net stable funding ratio based on Basel III accords (BIS, 2009).

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Bank liquidity creation and systemic risk ☆

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ABSTRACT

This paper examines the linkage between bank liquidity creation and systemic risk. Using quarterly data on U.S. bank holding companies from 2003 to 2016, we document that liquidity creation decreases systemic risk at the individual bank level after controlling for bank size, asset risk, and other bank-specific attributes. After decomposing systemic risk into bank-specific tail risk and systemic linkage, we find that the riskiness of individual banks is negatively linked to liquidity creation. Nevertheless, our results also demonstrate that liquidity creation strengthens the systemic linkage of individual banks to severe shocks in the financial system. Overall, our empirical findings demonstrate that the level of liquidity creation may have important implications for financial stability and the prudential supervision of financial institutions.

1. Introduction

This paper examines the linkage between bank liquidity creation and systemic risk. The process of liquidity creation by transforming liquid deposits into illiquid assets is one of the central roles of banks in the economy (Bhattacharya and Thakor, 1993; Berger and Bouwman, 2009,2017). While liquidity creation is a necessity for a well-functioning financial system and a crucial ingredient for economic growth and various macroeconomic outcomes (see e.g., Dell-Ariccia et al., 2008; Berger and Sedunov, 2017), the process of liquidity creation inherently reduces the liquidity of banks and exposes them to different types of risks, liquidity crunches, and bank runs (see e.g., Diamond and Dybvig, 1983; Kashyap, Rajan and Stein 2002; Berger and Bouwman, 2009). In general, previous studies have acknowledged that bank liquidity creation may not only affect the fragility of individual financial institutions but may also have severe negative externalities to overall financial stability (see e.g., Acharya and Naqvi, 2012; Fungáčová et al., 2015; Acharya and Thakor, 2016; Berger and Bouwman, 2017; Zheng, Cheung and Cronje, 2019). Liquidity crunches, for instance, can quickly propagate from one institution to another and trigger systemic financial instability as was seen during the global financial crisis of 2008–2009.

While the riskiness of individual banks taken in isolation is certainly important for financial stability, the global financial crisis revealed the importance of the collective fragility of financial institutions for the soundness of the financial system. As a consequence, many newly established supervisory authorities, such as the Financial Stability Oversight Council (FSOC) in the U.S. and the European Systemic Risk Board (ESRB) in the E.U. shifted regulatory attention towards a macro-prudential target of decreasing the systemic risk of financial institutions. If the process of liquidity creation may potentially increase the fragility of individual banks, how does it affect the overall fragility of the banking sector and the systemic risk posed by individual financial institutions? The objective of this paper is to empirically address this question.

Our empirical analysis builds upon two recent streams of research. First, our paper extends the relatively small body of literature on bank liquidity creation. Given that liquidity creation is a key reason for the existence of banks, it has received surprisingly little attention in prior empirical banking research. Banks create liquidity on their balance sheets by financing relatively illiquid

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asset such as long-term loans with relatively liquid liabilities such as demand deposits (Bryant, 1980; Diamond and Dybvig, 1983), and they can also create liquidity off their balance sheets through loan commitments or other kinds of claims such as standby letters of credit (Kashyap et al., 2002).

The role of bank liquidity creation for the macroeconomy and economic growth has been empirically examined in Fidrmuc at al (2015), Berger and Sedunov (2017), and Davydov et al., (2018). These studies show that liquidity creation is positively related to economic output and growth as well as business cycle fluctuations. Horváth et al. (2014), Berger, Bouwman, Kick and Schaeck (2016), Diaz and Huang (2017), and Fungáčová et al. (2017) examine how liquidity creation is affected by bank-specific attributes, regulatory environment, and policy actions. Their findings indicate that the level of liquidity creation is higher for banks with lower capital ratios and stronger corporate governance mechanisms Horváth et al. (2014); Diaz and Huang, 2017). Furthermore, the prior studies document that liquidity creation is affected by regulatory changes and interventions, bailouts, and deposit insurance systems (Berger et al., 2016; Fungáčová et al., 2017; Casu, di Pietro and Trujillo-Ponce, 2019; Jiang, Levine and Lin, 2019), but is largely unaffected by monetary policy (Berger and Bouwman, 2017).

Berger and Bouwman (2017) and Chatterjee (2018) investigate the linkage between aggregate bank liquidity creation and the development of financial crises and recessions. Berger and Bouwman (2017) document that periods of excessive detrended aggregate liquidity creation tend to be followed by financial crises, and furthermore, that especially the level of off-balance sheet liquidity creation is a useful predictor of an impending crisis. In contrast to Berger and Bouwman (2017), Chatterjee (2018) finds that declining bank liquidity creation may contain information about future recessions. His findings indicate that bank on-balance sheet liquidity creation starts to decrease roughly four quarters prior to recessions, and continues to fall leading up to a recession, implying that banks start to reduce liquidity creation before crises and recessions.

Perhaps most closely related to our study, Fungacova et al. (2015) and Zheng et al. (2019) examine whether bank failures are associated with liquidity creation. Fungacova et al. (2015) document that while extremely high levels of liquidity creation may cause bank liquidation, shortages in liquidity creation are associated with a greater probability of bank failure. Partially consistent with Fungacova et al. (2015), Zheng et al. (2019) find that the relationship between liquidity creation and the likelihood of bank failure is negative conditional on the amount of equity capital. Collectively, the prior empirical studies suggest that liquidity creation may influence financial stability as well as the fragility of individual banks.

Theoretical models proposed by Acharya and Naqvi (2012) and Acharya and Thakor (2016) can be used to posit a linkage between bank liquidity creation and the vulnerability of banks. Acharya and Naqvi (2012) develop a model that shows that excess bank liquidity encourages bank managers to take excessive risks by underpricing downside risk of lending policies. If deposits flow into banks and lending standards deteriorate, bank liquidity creation can generate asset price bubbles and increase the systemic vulnerability of the banking sector. Acharya and Thakor (2016) focus on the linkage between bank leverage, liquidity creation, and systemic risk. Their model indicates that higher bank leverage as an instrument of high liquidity creation may lead to greater systemic risk due to contagious bank runs when banks are being liquidated by their creditors.

In addition to the bank liquidity creation literature, our paper is related to the growing body of studies on systemic risk. In the aftermath of the global financial crisis, bank supervision authorities, regulators, and policymakers have devoted considerable attention to monitoring and measurement of systemic risk. Systemic risk can be broadly defined as the collective fragility of financial institutions and it reflects banks' asset risk, capital adequacy, their size, and their connections with the rest of the financial system. Over the past few years, numerous alternative measures to quantifying the level of systemic risk of individual financial institutions have been proposed in the literature (see e.g. Acharya, Engle, and Richardson, 2012; Billio, Getmansky, Lo and Pelizzon, 2012; Adrian and Brunnermeier, 2016; Brownlees and Engle 2017; Van Oordt and Zhou, 2019a).[1] Despite the amplified academic and regulatory interest toward the measurement of systemic risk, prior research about bank-specific attributes that may influence the level of systemic risk is still relatively scarce.

Brunnermeier, Dong and Palia (2012), Pais and Stork (2013), Mayordomo et al. (2014), Calluzzo and Dong (2015); Iqbal et al. (2015); Bostandzic and Weiß (2018), Fina Kamani (2019), and Van Oordt and Zhou (2019a) document that bank size, business model, the amount of equity capital, and the proportion of non-performing loans are important factors for explaining the systemic risk of financial institutions. More specifically, these prior studies suggest that larger institutions with lower capital ratios and greater involvement in nontraditional banking activities are associated with higher systemic risk. Anginer, Demirguc-Kunt and Zhu (2014) and Silva-Buston (2019) examine how bank competition affects systemic risk, and document that that increasing bank competition may reduce systemic fragility by encouraging risk diversification or by reducing the market power of individual banks. Finally, Berger, Roman and Sedunov (2020) examine the impact of the Troubled Assets Relief Program (TARP) on the systemic risk of the recipient banks. Their findings indicate that TARP decreased systemic risk especially for larger recipient banks associated with lower levels of ex ante systemic risk.

In this paper, we aim to contribute to the existing literature by examining the linkage between bank liquidity creation and systemic risk. Following the prior studies on bank liquidity creation (e.g., Berger and Bouwman, 2017; Berger and Sedunov, 2017; Davydov et al., 2018; Diaz and Huang, 2017; Jiang et al., 2019; Zheng et al., 2019), we utilize the three-step procedure of Berger and Bouwman (2009) to measure the level of liquidity creation of individual banks. Specifically, we use the measure of liquidity creation which incorporates all bank on-balance sheet and off-balance sheet activities as well as four alternative measures that distinguish between liquidity creation on the asset and liability sides of the balance sheet and between on-balance sheet and off-balance sheet activities. To gauge the contributions of individual banks to systemic risk, we employ the novel systemic risk measure developed by Van Oordt and Zhou (2019a). The key advantage of this market-based approach is that it enables us to decompose the systemic risk of individual banks into bank-specific tail risk and systemic linkage to severe shocks in the financial system.[2]

In our empirical analysis, we use quarterly data on publicly traded U.S. bank holding companies over the period 2003–2016. Our results demonstrate that liquidity creation decreases the systemic risk contribution of individual banks after controlling for bank size, funding and income structure, asset risk, and other bank-specific attributes. Furthermore, we document that liquidity creation both through the bank's on-balance sheet and off-

[1] Different approaches for measuring systemic risk are discussed and compared, for instance, in Bisias, Flood, Lo and Valavanis (2012), Rodriguez-Moreno and Pena (2013), Sedunov (2016), and Kleinow, Moreira, Strobl and Vahamaa (2017).

[2] In our additional tests, we also use the marginal expected shortfall (MES) and systemic risk (SRISK) proposed by Acharya et al. (2012,2017) and Brownlees and Engle (2017) to measure systemic risk in order to ensure that our empirical findings are robust to alternative systemic risk metrics.

balance sheet activities as well as liquidity creation on both the asset and liability sides of the balance sheet are negatively associated with the level of systemic risk. After decomposing systemic risk into bank-specific tail risk and systemic linkage, we find that the riskiness of individual banks is strongly negatively linked to liquidity creation. Thus, broadly consistent with the findings of Zheng et al. (2019), the results suggest that liquidity creation may decrease rather than increase risk at the individual bank level even though the process of liquidity creation is inherently risky and makes the banks less liquid. Nevertheless, our results also demonstrate that increasing liquidity creation may strengthen the systemic linkage of individual banks to severe shocks in the financial system. We conduct a number of additional tests which suggest that our empirical findings are robust to alternative variable definitions, different model specifications, and the inclusion of additional controls. These tests indicate, among other things, that the strength of the linkage between liquidity creation and systemic risk is influenced by bank size, funding structure, and the amount of equity capital.

Our paper contributes to the literature in a number of ways. Most importantly, to the best of our knowledge, this paper is the first to empirically examine the relationship between bank liquidity creation and systemic risk. While previous studies by Zheng et al. (2019) and Berger and Bouwman (2017) have documented that liquidity creation is associated with bank-specific insolvency risk and the outbreak of financial crises, we contribute to the literature by showing that liquidity creation is negatively linked to the systemic risk of individual banks. Furthermore, we complement and extend the work of Berger and Bouwman (2017) and Zheng et al. (2019) by decomposing systemic risk into bank-specific tail risk and systemic linkage. Consistent with the negative relation between liquidity creation and bank insolvency risk documented by Zheng et al. (2019), our findings indicate that liquidity creation decreases bank-specific tail risk. On the other hand, broadly consistent with the findings of Berger and Bouwman (2017) related to financial crises, our results also demonstrate that increasing liquidity creation can strengthen the systemic linkage of individual banks to severe shocks in the financial system. In general, these findings can be interpreted to indicate that bank-specific tail-risk dominates the systemic linkage component in invoking the observed negative association between liquidity creation and systemic risk at the individual bank level. Our results also provide new evidence to suggest that aggregate liquidity creation in the system and liquidity creation at the individual bank level may have opposite effects on systemic risk, thereby further iterating the complementary roles of micro-prudential and macro-prudential supervision of the banking industry.

The remainder of the paper is organized as follows. Section 2 describes the data and introduces the liquidity creation and systemic risk measures used in our empirical analysis. Section 3 first presents the empirical setup and then reports our empirical findings on the association between bank liquidity creation and systemic risk. Finally, Section 4 summarizes the findings and concludes the paper.

2. Data and variables

2.1. Data

The sample used in our empirical analysis consists of publicly traded U.S. bank holding companies (BHCs). We obtain data from three different sources: (i) daily stock price data used for estimating the level of systemic risk for individual banks are obtained from CRSP, (ii) quarterly data on the Berger and Bouwman (2009) measures of bank liquidity creation are collected from Christa Bouwman's data library[3], and (iii) the banks' financial statement and balance sheet variables come from the quarterly FR Y-9C reports available at the Federal Reserve Bank of Chicago data library.[4]

Given that the stock price data is at the bank holding company level and the Berger and Bouwman (2009) liquidity creation measures are calculated separately for each commercial bank, we consolidate the liquidity creation data by first identifying the top holder of each individual commercial bank and then aggregating bank-level liquidity creation at the BHC level. We then match the BHC-level stock price data with the consolidated liquidity creation measures and the consolidated financial statement data from the FR Y-9C reports.[5] After excluding banks with missing data as well as thinly-traded banks for which stock price remains unchanged for more than 60 percent of trading days, we obtain a sample of 472 individual bank holding companies and an unbalanced panel of 13,265 bank-quarter observations for the period ranging from the last quarter of 2003 to the last quarter of 2016.

2.2. Systemic risk

Our dependent variable is the systemic risk of individual bank holding companies. We utilize the market-based systemic risk measure developed by Van Oordt and Zhou (2019a) to gauge the contributions of individual banks to systemic risk. The key advantage of the market-based approach of Van Oordt and Zhou (2019a) is that it enables us to decompose the systemic risk of individual banks into bank-specific tail risk and systemic linkage to severe shocks in the financial system. This decomposition is important for two reasons. First, from the macro-prudential supervision perspective, for banks with the same level of stand-alone risk, those banks that are more sensitive to systemic shocks are systemically riskier. Second, from the micro-prudential perspective, for banks with the same sensitivity to severe shocks in the financial system, those banks that have a higher level of tail risk are more systemically risky.

Following Van Oordt and Zhou (2019a), we use stock market data to estimate systemic risk at the individual bank level. Specifically, systemic risk measure for each bank is constructed by regressing the bank's daily stock returns on the daily returns of the aggregate financial sector conditional on extreme shocks in the market:

$$R_i = \beta_i^T R_m + \varepsilon_i \ for \ R_m < -VaR_\alpha \tag{1}$$

where *VaR* denotes the value-at-risk in the financial system with the probability of α, R_i is bank *i*'s stock return and R_m is the return on the value-weighted index of financial institutions. β_i^T in Equation (1) corresponds to systemic risk at the individual bank level; a higher β_i^T indicates that bank *i* would suffer larger capital losses during periods of extreme market turmoil. Systemic risk is estimated using α of 5 percent which induces estimation uncertainty due to the small number of tail observations. To circumvent the obvious small sample problems, Van Oordt and Zhou (2019a) utilize Extreme Value Theory (EVT) to estimate systemic risk. Formally, β_i^T can be expressed as:

$$\beta_i^T = \lim_{\alpha \to 0} \tau_i(\alpha)^{1/\xi_m} \frac{VaR_i(\alpha)}{VaR_m(\alpha)} \tag{2}$$

[3] The Berger and Bouwman (2009) bank liquidity creation measures are publicly available from Christa Bouwman's data library at https://sites.google.com/a/tamu.edu/bouwman/data.

[4] The data on consolidated financial statements of U.S. bank holding companies are publicly available from the Federal Reserve Bank of Chicago data library at https://www.chicagofed.org/banking/financial-institution-reports/bhc-data.

[5] We utilize the CRSP-FRB link publicly available from the Federal Reserve Bank of New York website at https://www.newyorkfed.org/research/banking_research/datasets.html to match the FR Y-9C reports with CRSP stock price data.

where ξ_m is the market tail index and $\tau_i(\alpha)$ is the tail dependence between bank *i*'s stock returns and the market index defined as follows:

$$\tau_i(\alpha) = \Pr(R_i < -VaR_i(\alpha)|R_m < -VaR_m(\alpha)). \quad (3)$$

Van Oordt and Zhou (2019a) note that the parameters in Equation (2) can be estimated by applying EVT in a heavy-tailed environment. This estimation approach is developed and applied in Van Oordt and Zhou (2016,2019b). Van Oordt and Zhou (2019a) estimate β_i^T by combining the estimators of its two subcomponents. If the tail region is defined as the lowest *n* stock returns, β_i^Tcan be estimated as:

$$\beta_i^T = \tau_i(n/T)^{1/\xi_m}\frac{VaR_i(n/T)}{VaR_m(n/T)} \quad (4)$$

where the market tail index ξ_m is estimated following Hill (1975), *VaR* is estimated from the lowest *n* daily bank stock and market returns, $\tau_i(n/T)$ is estimated nonparametrically following Embrechts, De Haan and Huang (2000), and *T* is the number of daily return observations in the estimation window.

As can be noted from Equation (4), systemic risk of individual banks β_i^T consists of two components. The first component $\tau_i(n/T)^{1/\xi_m}$ measures the systemic linkage of individual banks to severe shocks in the financial system. This component can be interpreted as the proportion of bank *i*'s tail risk that is associated with extreme market shocks. The second component $\frac{VaR_i(n/T)}{VaR_m(n/T)}$ measures the level of bank-specific tail risk. This component is simply the ratio between *VaR* of bank *i* and *VaR* of the aggregate financial sector; the higher the ratio, the higher the tail risk of bank *i* relative to the index of financial institutions.

By taking the logarithm of Equation (4), we obtain the following linear additive relationship between systemic risk, systemic linkage, and bank-specific tail risk:

$$\log(\beta_i^T) = \log\ \tau_i\left(\frac{n}{T}\right)^{\frac{1}{\xi_m}} + \log\ \frac{VaR_i(n/T)}{VaR_m(n/T)} \quad (5a)$$

$$\log(Systemic\ risk) = \log(Systemic\ linkage) + \log(Tail\ risk). \quad (5b)$$

In our empirical analysis, we use *Systemic risk*, *Systemic linkage*, and *Tail risk* as the dependent variables to examine whether and how bank liquidity creation influences systemic risk and its two subcomponents. We estimate these three variables for each bank and each quarter by using two years of daily stock return data with a quarterly rolling estimation window.[6]

2.3. Liquidity creation

Following the prior literature (e.g., Berger and Bouwman, 2017; Berger and Sedunov, 2017; Davydov et al., 2018; Diaz and Huang, 2017; Jiang et al., 2019; Zheng et al., 2019), we utilize the three-step procedure of Berger and Bouwman (2009) to measure the level of liquidity creation of individual banks. This procedure is briefly outlined in Appendix 1.

In the first step, banks' on-balance sheet and off-balance sheet activities (e.g. assets, liabilities, equity, derivatives, and guarantees) are classified as illiquid, semi-liquid or liquid. The classification of assets and liabilities is based on the ease, cost, and time for the bank to provide liquidity for customers when requested. In the second step, positive (+1/2), negative (-1/2), and zero weights are assigned to each on-balance sheet and off-balance sheet item classified in the first step. The assigned weights are in parallel with financial intermediation theory arguing that liquidity is created on-balance sheet when illiquid assets are transformed into liquid liabilities. In other words, banks create liquidity by removing illiquid items (e.g. long-term illiquid assets) from the public and in return provide liquid items for the public (e.g. short-term deposits). A positive (+1/2) weight is given to liquid liabilities and illiquid assets, and a negative (-1/2) weight is given to illiquid liabilities and equity capital and liquid assets. The zero weight is assigned to semi-liquid items. In this regard, banks can create the maximum amount of liquidity if illiquid assets are financed by liquid liabilities.

Finally, in the third step, all bank activities classified in the first step and all weights assigned in the second step are combined to obtain a measure of bank liquidity creation. In the parlance of Berger and Bouwman (2009), this liquidity creation measure is referred to as "cat fat". In addition to total liquidity creation (*Total LC*), we also use two alternative liquidity creation measures which only include either on-balance sheet activities (*On-Bs LC*) or off-balance sheet activities (*Off-Bs LC*) as well as two measures which only include liquidity creation on the asset side (*Asset-side LC*) or on the liability side (*Liability-side LC*) of the bank's balance sheet.

Similar to Berger and Bouwman (2009) and Fungacova et al. (2015), Jiang et al. (2019), Zheng et al. (2019), we scale the five alternative liquidity creation variables by total assets to improve comparability across banks and in order to mitigate the potentially disproportionate influence of the largest banks. We also trim the liquidity creation measures at the 0.5^{th} and 99.5^{th} percentiles to moderate the effects of extreme observations and outliers.

2.4. Control variables

The riskiness of banks is influenced by institution-specific characteristics such as size, the amount of equity capital, profitability, and income and funding structure (see e.g., Pathan 2009; Bai and Elyasiani 2013; Berger, Kick and Schaeck, 2014; González, Gil, Cunill and Lindahl, 2016; Berger, El Ghoul, Guedhami and Roman, 2017; Zheng et al., 2019). To account for the potentially confounding effects of bank-specific factors on systemic risk, we employ the following set of control variables in our regressions: (i) *Size* is measured as the natural logarithm of total assets, (ii) *Capital ratio* is the ratio of equity capital to total assets, (iii) *Profitability* is measured with return on assets (ROA) which is calculated as the ratio of net income to total assets, (iv) *Deposits to assets* calculated as total deposits divided by total assets is used as a control for funding structure, (v) *Non-interest income* calculated as the ratio of non-interest income to interest income is utilized as a proxy for income structure and business model, and (vi) *Non-performing loans* defined as the ratio of non-performing loans to total loans controls for the quality and riskiness of banks' loan portfolios.

Previous studies indicate that the above bank characteristics are important factors for explaining the cross-sectional variation in systemic risk. Unsurprisingly, given that larger institutions are likely to have greater systemic importance, Brunnermeier et al. (2012); Pais and Stork (2013); Anginer et al. (2014); Iqbal and Vähämaa (2019); Silva-Buston (2019); Van Oordt and Zhou (2019a) document that systemic risk is positively associated with bank size. As noted by Brownlees and Engle (2017), equity capital and the degree of undercapitalization of financial institutions reflect the level of systemic risk in the entire financial system, and individual banks with lower capital ratios are associated with higher levels of systemic risk (e.g., Mayordomo et al., 2014; Acharya and Thakor, 2016; Van Oordt and Zhou, 2019a; Berger et al., 2020). Moreover, previous studies have documented that the systemic risk of individual banks is negatively associated with profitability and the amount of deposit funding, while higher levels of

[6] In our additional tests, we also use an estimation window of four years to construct *Systemic risk*, *Systemic linkage*, and *Tail risk*.

non-interest income and non-performing loans are found to increase systemic risk (e.g., Brunnermeier et al., 2012; Iqbal et al., 2015; Bostandzic and Weiß, 2018; Fina Kamani, 2019; Van Oordt and Zhou, 2019a; Berger et al., 2020).

2.5. Descriptive statistics and correlations

Table 1 reports descriptive statistics for our three different dependent variables (*Systemic risk, Systemic linkage*, and *Tail risk*), for the five alternative liquidity creation measures (*Total LC, On-Bs LC, Off-Bs LC, Asset-side LC*, and *Liability-side LC*), and for the control variables. The descriptive statistics demonstrate that there is considerable dispersion across banks in the level of systemic risk. *Systemic risk* varies from a minimum of 0.17 to a maximum of 4.01 with a mean of 1.01. As expected, the mean value of *Systemic risk* indicates that, on average, the exposure of individual banks to tail shocks corresponds to the loss in the aggregate financial sector. *Tail risk* ranges from 0.46 to 8.26 and *Systemic linkage* from 0.24 to 0.95, with means of 1.66 and 0.62, respectively. These figures are very similar to the systemic risk estimates reported in Van Oordt and Zhou (2019a). The banks included in our sample are also heterogeneous in terms of liquidity creation. Table 1 shows that *Total LC* varies between -4.8 and 83 percent with a mean of 43 percent. The mean value amounts to about $15 billion, and the negative values of *Total LC* indicate that banks sometimes also destroy liquidity, for instance, by financing illiquid liabilities with liquid assets. On average, the on-balance sheet liquidity creation relative to the bank's total assets is about 34 percent, while off-balance sheet liquidity creation corresponds to 9.7 percent of total assets. The mean *Asset-side LC* and *Liability-side LC* are 13.3 and 20.5 percent of total assets, respectively.

Table 1 further shows that the sample comprises very different types of banks in terms of their size, capital ratios, financial performance as well as income and funding structure. The amount of total assets varies substantially from about $280 million to $2.6 trillion, with a mean of $36 billion. The sample banks, on average, hold capital ratios of 9.6 percent and have quarterly ROA of 0.4 percent, which results in an average annualized ROA of about 1.6 percent. The deposits-to-assets ratio ranges from a minimum of 7.3 to a maximum of 99.8 percent with a mean of 77 percent, and the ratio of non-interest income to interest income varies considerably around its mean of 26 percent. Overall, it can be concluded from Table 1 that the sample exhibits considerable heterogeneity with respect to the dependent and the independent variables.

Table 2 presents the bivariate correlations between the variables used in our main regressions. As can be seen from the table, *Systemic risk* is strongly positively correlated with *Tail risk* and *Systemic linkage*, while *Tail risk* and *Systemic linkage* are negatively correlated with each other. Not surprisingly, *Total LC* is positively correlated with the four alternative bank liquidity creation measures. Regarding the linkage between bank liquidity creation and systemic risk, the correlations indicate that *Systemic risk* is positively associated with all five liquidity creation measures. Furthermore, *Tail risk* is strongly positively correlated with *Asset-side LC* and negatively correlated with *Liability-side LC*, while *Systemic linkage* is strongly positively correlated with *Off-Bs LC* and *Liability-side LC* and negatively correlated with *Asset-side LC*.

Table 2 also shows that the systemic risk measures are correlated with most of our control variables. *Size* is strongly positively correlated with *Systemic risk, Systemic linkage*, and *Off-Bs LC*, suggesting that larger banks are associated with higher systemic risk, stronger linkage to systemic shocks, and higher levels of off-balance sheet liquidity creation. Furthermore, it can be noted that many of our control variables are relatively highly correlated with each other. The highest correlation coefficients are those between *Size* and *Non-interest income* ($r = 0.48$) and *Size* and *Deposits to as-*

Table 1
Descriptive statistics.

	Mean	Median	St.dev.	Min	Max	No. of obs.
Dependent variables:						
Systemic risk	1.013	0.984	0.380	0.173	4.011	14317
Tail risk	1.664	1.511	0.618	0.458	8.264	14317
Systemic linkage	0.623	0.639	0.162	0.238	0.947	14317
Liquidity creation:						
Total LC	0.434	0.440	0.136	-0.048	0.825	14975
On-Bs LC	0.337	0.345	0.118	-0.306	0.729	14975
Asset-side LC	0.133	0.142	0.118	-0.448	0.472	14975
Liability-side LC	0.205	0.203	0.070	-0.036	0.437	14975
Off-Bs LC	0.097	0.084	0.062	0.001	0.791	14975
Control variables:						
Size	36300	1993	218000	277	2580000	14529
Capital ratio	0.096	0.095	0.023	0.004	0.173	14437
Profitability	0.004	0.004	0.009	-0.137	0.058	14529
Deposits to assets	0.769	0.785	0.089	0.073	0.998	14529
Non-interest income	0.261	0.208	0.205	-0.009	1.844	14285
Non-performing loans	0.002	0.000	0.006	0.000	0.107	14529

The table reports descriptive statistics for 472 bank holding companies over the period 2003-2016. *Systemic risk* is the Van Oordt and Zhou (2019a) systemic risk measure at the individual bank level, *Systemic linkage* is the systemic linkage of individual banks to severe shocks in the financial system, and *Tail risk* measures the level of bank-specific tail risk. The liquidity creation measures are defined as follows: *Total LC* is the Berger and Bouwman (2009) total liquidity creation scaled by total assets, *On-Bs LC* is the amount of liquidity created through on-balance sheet activities scaled by total assets, *Asset-side LC* is the amount of liquidity created on the asset side of the bank's balance sheet scaled by total assets, *Liability-side LC* is the amount of liquidity created on the liability side of the bank's balance sheet scaled by total assets, and *Off-Bs LC* is the amount of liquidity created through off-balance sheet activities scaled by total assets. The bank-specific control variables are defined as follows: *Size* is measured by total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans.

Table 2
Correlations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Systemic risk													
(2) Tail risk	0.714												
(3) Systemic linkage	0.507	-0.220											
(4) Total LC	0.108	-0.005	0.165										
(5) On-Bs LC	0.040	0.032	0.004	0.893									
(6) Asset-side LC	0.018	0.122	-0.141	0.722	0.820								
(7) Liability-side LC	0.037	-0.150	0.242	0.285	0.300	-0.301							
(8) Off-Bs LC	0.163	-0.071	0.358	0.511	0.070	0.034	0.060						
(9) Size	0.283	-0.214	0.717	0.188	-0.096	-0.179	0.138	0.601					
(10) Capital ratio	0.064	-0.183	0.327	0.135	0.129	0.034	0.159	0.051	0.216				
(11) Profitability	-0.004	-0.088	0.101	0.039	-0.018	-0.130	0.186	0.121	0.069	0.268			
(12) Deposits to assets	-0.052	0.116	-0.234	0.186	0.368	0.191	0.295	-0.291	-0.432	-0.044	-0.096		
(13) Non-interest income	0.084	-0.166	0.361	0.023	-0.159	-0.312	0.257	0.353	0.475	0.135	0.156	-0.253	
(14) Non-performing loans	0.052	-0.101	0.235	0.026	-0.053	-0.051	-0.003	0.159	0.342	0.140	-0.004	-0.128	0.198

The table reports bivariate correlations between the variables used in the regressions. The three dependent variables are defined as follows: *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level, *Systemic linkage* is the natural logarithm of systemic linkage of individual banks to severe shocks in the financial system, and *Tail risk* is the natural logarithm of bank-specific tail risk. The liquidity creation measures are defined as follows: *Total LC* is total liquidity creation scaled by total assets, *On-Bs LC* is the amount of liquidity created through on-balance sheet activities scaled by total assets, *Asset-side LC* is the amount of liquidity created on the asset side of the bank's balance sheet scaled by total assets, *Liability-side LC* is the amount of liquidity created on the liability side of the bank's balance sheet scaled by total assets, and *Off-Bs LC* is the amount of liquidity created through off-balance sheet activities scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1^{st} and 99^{th} percentiles.

sets ($r = -0.43$). Overall, the correlations in Table 2 demonstrate the importance of size when comparing financial institutions as the dependent variables and all of the independent variables are relatively strongly correlated with bank size.

3. Empirical analysis

3.1. Main results

We examine the linkage between bank liquidity creation and systemic risk by estimating alternative fixed-effects panel regressions of the following form:

$$\begin{aligned}\log(\text{Risk}_{i,t}) = \alpha + \beta\text{Liquidity creation}_{i,t-1} \\ +\gamma(\text{Bank-specific controls})_{i,t-1} \\ +\omega(\text{Bank fixed-effects})_{i,t} \\ +\varphi(\text{Time fixed-effects})_{i,t} \\ +\varepsilon_{i,t} \qquad (6)\end{aligned}$$

where the dependent variable $Risk_{i,t}$ is the natural logarithm of one of three alternative systemic risk measures (*Systemic risk, Systemic linkage*, or *Tail risk*) for bank *i* at time *t*. Following Van Oordt and Zhou (2019a), we exclude all observations for which the estimate of *Systemic risk* equals zero in order to preserve the additive relationship between systemic risk and its two subcomponents. *Liquidity creation*$_{i,t}$ in Equation (6) is one of the following liquidity creation measures for bank *i* at time *t*: (i) *Total LC* is total liquidity creation which incorporates the bank's on-balance sheet and off-balance sheet activities, (ii) *On-Bs LC* includes only on-balance sheet activities, (iii) *Off-Bs LC* includes only off-balance sheet activities, (iv) *Asset-side LC* includes liquidity creation on the asset side of the balance sheet, and (v) *Liability-side LC* includes liquidity creation on the liability side of the balance sheet. Similar to Berger and Bouwman (2009), we scale the liquidity creation measures by the bank's total assets.

The set of bank-specific control variables includes *Size, Capital ratio, Profitability, Deposits to assets, Non-interest income*, and *Non-performing loans*. All the explanatory variables in Equation (6) are lagged by one quarter in order to mitigate potential simultaneity problems. Furthermore, we include bank fixed-effects to control for time-invariant unobserved heterogeneity and biases related to potentially omitted explanatory variables as well as time fixed-effects to account for time-specific unobservable factors which may systematically influence the level of systemic risk. Throughout the regressions, we use robust standard errors which are adjusted for heteroscedasticity and are clustered by bank.

Table 3 reports the estimates of Equation (6) with *Systemic risk* as the dependent variable. In Model 1, total liquidity creation is used as the independent variable of interest, while in Models 2 and 3, total liquidity creation is decomposed into on-balance sheet and off-balance sheet liquidity creation, and liquidity creation on the asset and liability sides of the balance sheet, respectively. As shown in Table 3, the adjusted R^2s indicate that our fixed-effects panel regressions can explain about 36 percent of the variation in systemic risk.

Overall, the regression results in Table 3 demonstrate that bank liquidity creation is negatively associated with the systemic risk of individual banks. The coefficient estimates for all five alternative liquidity creation measures are negative and statistically highly significant. Thus, our regressions suggest that liquidity created both through the bank's on-balance sheet and off-balance sheet activities as well as liquidity creation on both the asset and liability sides of the balance sheet decrease systemic risk at the individual bank level. The magnitudes of the estimated coefficients suggest that a one standard deviation increase in *Total LC* would be associated with a nearly 5 percent decrease in *Systemic risk*, while corresponding increases in the four subcomponents of liquidity creation would decrease *Systemic risk* by about 3.5 to 5.5 percent with *Liability-side LC* having the largest effect among the subcomponents. Therefore, the observed negative linkage between liquidity creation and systemic risk can be considered economically significant. Although the process of liquidity creation is inherently risky and makes banks less liquid, our results indicate that liquidity creation decreases rather than increases systemic risk at the individual bank level. This finding is broadly consistent with Zheng et al. (2019), who document that liquidity creation decreases stand-alone risk and the likelihood of bank failure.

With respect to our control variables, the estimates in Table 3 demonstrate the importance of these variables as determinants of systemic risk. Specifically, the regression results indicate that *Systemic risk* is significantly positively associated with *Size, Deposits to assets*, and *Non-performing loans*, while being negatively related to *Capital ratio* and *Profitability*. Thus, consistent

Table 3
Liquidity creation and systemic risk.

	Model (1)	Model (2)	Model (3)
Liquidity creation:			
Total LC	-0.357***		
	(-3.50)		
On-Bs LC		-0.283**	
		(-2.17)	
Off-Bs LC		-0.557**	
		(-2.10)	
Asset-side LC			-0.298**
			(-2.23)
Liability-side LC			-0.779***
			(-3.18)
Control variables:			
Size	0.069**	0.069**	0.065*
	(2.00)	(2.00)	(1.89)
Capital ratio	-1.371***	-1.390***	-1.498***
	(-2.81)	(-2.87)	(-3.05)
Profitability	-4.999***	-4.961***	-4.910***
	(-6.91)	(-6.91)	(-6.76)
Deposits to assets	0.264*	0.247	0.328**
	(1.66)	(1.56)	(2.07)
Non-interest income	-0.072	-0.070	-0.064
	(-1.16)	(-1.13)	(-1.02)
Non-performing loans	3.109***	3.098**	3.040***
	(2.58)	(2.51)	(2.61)
Constant	-1.236**	-1.221**	-1.168**
	(-2.24)	(-2.22)	(-2.13)
No. of banks	472	472	472
No. of observations	13,265	13,265	13,265
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.36	0.36	0.36

The table reports the estimates of three alternative versions of Equation (6). The dependent variable *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level. The liquidity creation measures are defined as follows: *Total LC* is total liquidity creation scaled by total assets, *On-Bs LC* is the amount of liquidity created through on-balance sheet activities scaled by total assets, *Off-Bs LC* is the amount of liquidity created through off-balance sheet activities scaled by total assets, *Asset-side LC* is the amount of liquidity created on the asset side of the bank's balance sheet scaled by total assets, and *Liability-side LC* is the amount of liquidity created on the liability side of the bank's balance sheet scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1st and 99th percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

with the prior systemic risk literature (e.g., Pais and Stork, 2013; Bostandzic and Weiß, 2018; Iqbal and Vähämaa, 2019; Van Oordt and Zhou, 2019a; Berger et al., 2020), our estimates suggest that larger banks which have lower capital ratios, weaker financial performance, and more risky loan portfolios are associated with higher levels of systemic risk.

As the next step of our analysis, we decompose the systemic risk of individual banks into bank-specific tail risk and systemic linkage to severe shocks in the financial system. The estimation results of six alternative versions of Equation (6) with *Systemic linkage* and *Tail risk* as the dependent variables are reported in Table 4. All regressions include the full set of control variables as well as bank and year fixed-effects to account for any time-invariant firm-specific heterogeneity and time-specific systematic variation in systemic risk. The adjusted R^2s of the alternative regression specifications range from about 36 percent to 52 percent.

Intriguingly, the estimates in Table 4 indicate that bank liquidity creation is negatively associated with *Tail risk*, while being positively related to *Systemic linkage*. This suggests that the negative effect of liquidity creation on systemic risk is driven by the negative relationship between liquidity creation and bank-specific tail risk. As can be noted from Table 4, the coefficients for *Total LC, On-Bs LC, On-Bs LC, Asset-side LC*, and *Liability-side LC* are all negative and statistically significant at the 1 percent level in Models 1-3 with *Tail risk* as the dependent variable. The coefficient estimate for *Total LC* suggests that a standard deviation increase in total liquidity creation is associated with a 6.6 percent decrease in bank-specific tail risk, and similar increases in on-balance sheet, off-balance sheet, asset-side, and liability-side liquidity creation would decrease bank tail risk by approximately 4.2 to 6.5 percent.

In Models 4-6 with *Systemic linkage* as the dependent variable, the coefficient estimates for *Total LC, On-Bs LC, Off-Bs LC*, and *Asset-side LC* are positive and significant, and also the coefficient for *Liability-side LC* is positive, albeit being insignificant. The magnitudes of these coefficients indicate that one standard deviation increases in the liquidity creation measures correspond to about 4-5 percent increase in the degree of systemic linkage. Taken as a whole, the estimates in Table 4 suggest that while liquidity creation may decrease bank-specific tail risk and systemic risk at the individual bank level, it may also strengthen the systemic linkage of individual banks to severe shocks in the financial system.

Similar to Van Oordt and Zhou (2019a), the estimated coefficients for the control variables in Table 4 indicate that *Size* is negatively related to *Tail risk* and positively related to *Systemic linkage*, suggesting that larger banks are more sensitive to severe shocks in the financial system despite being individually associated with lower tail risk. In addition to bank size, *Tail risk* is significantly positively associated with *Deposits to assets* and *Non-performing loans* and negatively associated with *Capital ratio* and *Profitability*, while *Systemic linkage*, in turn, is positively related to *Capital ratio* and *Profitability*.

In general, the regression results in Tables 3 and 4 demonstrate that the linkage between bank liquidity creation and systemic risk is negative. Our estimates provide strong evidence that liquidity created both through the bank's on-balance sheet and off-balance sheet activities as well as liquidity creation on both the asset and liability sides of the balance sheet decrease the systemic risk of individual banks. After decomposing systemic risk into bank-specific tail risk and systemic linkage, we observe that the negative effect of liquidity creation on systemic risk is driven by its negative relation to bank-specific tail risk. Nevertheless, our results also suggest that liquidity creation may strengthen the systemic linkage of individual banks to severe shocks in the financial system. Collectively, these findings can be interpreted to indicate that bank-specific tail-risk dominates the systemic linkage component in invoking the observed negative association between liquidity creation and systemic risk at the individual bank level.

3.2. The role of liquidity creation in the system

It is important to acknowledge that systemic risk at the individual bank level is determined not only by bank-level attributes and choices but also by the strategic decisions of other banks in the system. Therefore, the exposure to systemic risk, and especially to the systemic linkage component of systemic risk, is likely to be influenced by the aggregate level of liquidity creation in the banking system. It is also possible that herding effects occur and individual banks alter their liquidity creation in response to other banks' liquidity creation decisions. As a consequence, bank liquidity creation and systemic risk can be endogenously related. In the following, we conduct three additional tests to address these concerns.

Table 4
Liquidity creation and the subcomponents of systemic risk.

	Tail risk			Systemic linkage		
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Liquidity creation:						
Total LC	-0.484***			0.375***		
	(-5.56)			(3.20)		
On-Bs LC		-0.357***			0.286*	
		(-3.07)			(1.74)	
Off-Bs LC		-0.827***			0.613**	
		(-3.40)			(2.42)	
Asset-side LC			-0.412***			0.380**
			(-3.57)			(2.27)
Liability-side LC			-0.923***			0.417
			(-4.34)			(1.37)
Control variables:						
Size	-0.084***	-0.084***	-0.089***	0.398***	0.399***	0.399***
	(-2.83)	(-2.86)	(-3.04)	(9.05)	(9.05)	(8.96)
Capital ratio	-2.481***	-2.514***	-2.625***	3.086***	3.109***	3.109***
	(-5.31)	(-5.42)	(-5.53)	(5.35)	(5.38)	(5.40)
Profitability	-5.643***	-5.579***	-5.592***	2.340***	2.295***	2.457***
	(-8.17)	(-8.09)	(-8.01)	(2.66)	(2.62)	(2.82)
Deposits to assets	0.335**	0.307**	0.399***	-0.122	-0.102	-0.125
	(2.32)	(2.13)	(2.74)	(-0.63)	(-0.52)	(-0.64)
Non-interest income	-0.057	-0.054	-0.049	-0.011	0.012	-0.008
	(-1.06)	(-1.01)	(-0.91)	(-0.15)	(0.18)	(-0.11)
Non-performing loans	2.399*	2.380*	2.330*	2.519	2.532	2.510
	(1.76)	(1.72)	(1.74)	(1.42)	(1.43)	(1.38)
Constant	1.744***	1.771***	1.813***	-5.954***	-5.973***	-5.943***
	(3.70)	(3.78)	(3.89)	(-8.82)	(-8.82)	(-8.62)
No. of banks	472	472	472	472	472	472
No. of observations	13,265	13,265	13,265	13,265	13,265	13,265
Bank fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.52	0.52	0.52	0.36	0.36	0.36

The table reports the estimates of six alternative versions of Equation (6). The dependent variables are defined as follows: *Tail risk* is the natural logarithm of bank-specific tail risk and *Systemic linkage* is the natural logarithm of systemic linkage of individual banks to severe shocks in the financial system. The liquidity creation measures are defined as follows: *Total LC* is total liquidity creation scaled by total assets, *On-Bs LC* is the amount of liquidity created through on-balance sheet activities scaled by total assets, *Off-Bs LC* is the amount of liquidity created through off-balance sheet activities scaled by total assets, *Asset-side LC* is the amount of liquidity created on the asset side of the bank's balance sheet scaled by total assets, and *Liability-side LC* is the amount of liquidity created on the liability side of the bank's balance sheet scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1^{st} and 99^{th} percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

First, we estimate regressions in which we use the liquidity creation of similar-sized peer banks as an additional control variable. To accomplish this, we utilize the Federal Financial Institutions Examination Council's (FFIEC) peer group classifications to divide the banks into the following five size categories: (i) peer group 1 comprises banks with total assets in excess of $100 billion, (ii) peer group 2 banks with total assets between $10 billion and $100 billion, (iii) peer group 3 banks with total assets between $3 and $10 billion, (iv) peer group 4 banks with total assets between $1 billion and $3 billion, and (v) peer group 5 banks with total assets below $1 billion. We calculate the average of the total liquidity creation scaled by total assets of banks in each peer group in each quarter, and then use this measure lagged by one quarter to control for the level of liquidity creation of other banks in the system.

The regression results with the liquidity creation of similar-sized banks as an additional control variable are presented in Panel A of Table 5. The estimates of Models 1-3 in Panel A are virtually identical to those reported in Tables 3 and 4; the coefficient estimates for *Total LC* are negative and significant in the *Systemic risk* and *Tail risk* regressions and positive and significant in the *Systemic linkage* regression. With respect to the liquidity creation of other banks, the results indicate that the average total liquidity creation of similar-sized peer banks is significantly positively associated with systemic risk and its two subcomponents at the individual bank level.

Second, as an alternative approach to control for the liquidity creation of other banks in the system, we use the aggregate amount of liquidity creation by peer group 1 banks in each quarter lagged by one quarter as an additional control variable in the regressions. The underlying logic is that the largest banks have a dominant position in the banking industry, and their strategic decisions and choices, for instance, with respect to liquidity creation shape the market environment for other banks. Thus, it is conceivable that the liquidity creation of the largest banks may influence the choices of smaller banks in the system.

In Models 4-6 reported in Panel A of Table 5, we include the natural logarithm of the total liquidity creation in dollars by peer group 1 banks as a control variable while excluding peer group 1 banks from the sample used in the estimation. The regression results are again very similar to our main regressions in Tables 3 and 4. As can be seen from Panel A, the coefficients for *Total LC* are negative and significant at the 1 percent level in the regressions

Table 5
The role of liquidity creation in the system.

	Systemic risk Model (1)	Tail risk Model (2)	Systemic linkage Model (3)	Systemic risk Model (4)	Tail risk Model (5)	Systemic linkage Model (6)
Panel A: Liquidity creation of other banks in the system						
Liquidity creation:						
Total LC	-0.352***	-0.480***	0.377***	-0.327***	-0.442***	0.363***
	(-3.46)	(-5.50)	(3.22)	(-3.01)	(-4.76)	(2.91)
Control variables:						
LC of peer banks	0.008***	0.007***	0.004***			
	(3.30)	(2.76)	(2.40)			
LC of peer group 1				0.431***	0.300***	0.300**
				(4.02)	(3.24)	(2.43)
Size	0.068**	-0.085***	0.398***	0.073**	-0.088***	0.417***
	(1.97)	(-2.85)	(9.03)	(2.05)	(-2.93)	(9.22)
Capital ratio	-1.405***	-2.511***	3.069***	-1.414***	-2.567***	3.158***
	(-2.89)	(-5.39)	(5.30)	(-2.84)	(-5.41)	(5.38)
Profitability	-4.922***	-5.577***	2.379***	-4.982***	-5.602***	2.210**
	(-6.95)	(-8.18)	(2.71)	(-6.82)	(-8.14)	(2.49)
Deposits to assets	0.269*	0.339**	-0.120	0.260	0.327**	-0.157
	(1.68)	(2.34)	(-0.62)	(1.59)	(2.20)	(-0.81)
Non-interest income	-0.071	-0.056	-0.011	-0.085	-0.070	-0.005
	(-1.16)	(-1.06)	(-0.15)	(-1.28)	(-1.30)	(-0.06)
Non-performing loans	3.131***	2.419*	2.530	1.486	0.048	4.354**
	(2.59)	(1.77)	(1.42)	(1.22)	(0.04)	(2.44)
Constant	-1.229**	1.750***	-5.951***	-10.584***	-4.657***	-12.632***
	(-2.23)	(3.71)	(-8.81)	(-5.56)	(-2.85)	(-5.74)
No. of banks	472	472	472	462	462	462
No. of observations	13,265	13,265	13,265	12,758	12,758	12,758
Bank fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.36	0.52	0.36	0.38	0.55	0.37

Panel B: Detrended liquidity creation	Systemic risk Model (1)	Tail risk Model (2)	Systemic linkage Model (3)
Liquidity creation:			
Detrended total LC	-0.091***	-0.048***	-0.122*
	(-2.70)	(-2.57)	(-1.90)
Control variables:			
Size	0.070**	-0.087***	0.410***
	(2.04)	(-2.98)	(9.30)
Capital ratio	-1.536***	-2.700***	3.244***
	(-3.11)	(-5.67)	(5.64)
Profitability	-5.309***	-6.063***	2.663***
	(-7.37)	(-8.58)	(3.05)
Deposits to assets	0.177	0.206	0.001
	(1.08)	(1.38)	(0.01)
Non-interest income	-0.077	-0.065	-0.002
	(-1.27)	(-1.22)	(-0.03)
Non-performing loans	3.133***	2.409*	2.560
	(2.67)	(1.77)	(1.38)
Constant	-1.306**	1.721***	-6.089***
	(-2.40)	(3.73)	(-8.93)
No. of banks	472	472	472
No. of observations	13,265	13,265	13,265
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.36	0.51	0.36

The table reports the estimates of alternative versions of Equation (6). The dependent variables are defined as follows: *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level, *Tail risk* is the natural logarithm of bank-specific tail risk, and *Systemic linkage* is the natural logarithm of systemic linkage of individual banks to severe shocks in the financial system. The liquidity creation measure are defined as follows: *Total LC* is total liquidity creation scaled by total assets, *LC of peer banks* is the average total liquidity creation scaled by total assets of similar-sized peer banks, *LC of peer group 1* is the natural logarithm of the total liquidity creation in dollars by banks in FFIEC peer group 1, and *Detrended total LC* is the detrended *Total LC*. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1^{st} and 99^{th} percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively with *Systemic risk* and *Tail risk* as the dependent variables, while being positive and significant in the regression with *Systemic linkage* as the dependent variable. The coefficient for the liquidity creation of peer group 1 banks is positive and highly significant in all three regressions and thereby indicates that the total amount of liquidity created by the largest and systemically most important banks increases the systemic risk of other banks in the system. In general, the additional tests in Panel A suggest that aggregate liquidity creation in the system and liquidity creation at the individual bank level may have opposite effects on systemic risk.

Third, as noted by Berger and Bouwman (2017), bank liquidity creation has increased persistently over time while also exhibiting periodical fluctuations around the long-run trend. These fluctuations may occur if many banks in the system increase or decrease liquidity creation simultaneously, or if increasing liquidity creation of large banks, for instance, induces a herding effect among smaller banks. Therefore, we follow Berger and Bouwman (2017) and use a detrended liquidity creation measure to investigate how deviations from the trend influence systemic risk at the individual bank level. Specifically, we utilize the Hodrick and Prescott (1997) filter to detrend bank liquidity creation and then use the detrended *Total LC* as the test variable of interest in our regressions. The results of these regressions are reported in Panel B of Table 5. Overall, the estimates based on detrended liquidity creation are qualitatively similar to our main regressions and indicate that bank liquidity creation is negatively associated with *Systemic risk* and *Tail risk*. However, inconsistent with the results in Table 4, the coefficient for detrended *Total LC* is negative and significant at the 10 percent level in the regression with *Systemic linkage* as the dependent variable. Intuitively, the negative relationship between detrended liquidity creation and systemic linkage can be reconciled by considering that a deviation from the trend may make the bank inherently less connected with other banks in the system.

3.3. High vs. low liquidity creation

A question that naturally arises from the documented negative relationship between bank liquidity creation and systemic risk is whether the effect is similar for banks that create high and low levels of liquidity. Specifically, the negative relationship can be driven, for instance, by either very high or very low liquidity creators. To investigate potential asymmetries in the relationship between liquidity creation and systemic risk, we replace our total liquidity creation measure *Total LC* by dummy variables for high and low levels of liquidity creation. We define *High LC* as a dummy which equals one for banks with *Total LC* in the top quintile in a given quarter, and correspondingly, *Low LC* is defined as a dummy that identifies banks with *Total LC* in the bottom quintile. The estimates of three different dummy variable regressions that control for potential non-linear effects of liquidity creation on systemic risk are presented in Table 6. These regressions again include the full set of control variables as well as bank fixed-effects and year fixed-effects. The adjusted R^2s of the dummy variable specifications are similar to our main regressions and range from 36 percent to 52 percent.

As can be seen from Table 6, the coefficient estimates for *Low LC* are positive and highly significant in the regressions with *Systemic risk* and *Tail risk* as the dependent variables, while the coefficients for *High LC* are negative and statistically significant. The coefficients suggest that banks that create low levels of liquidity are associated with nearly 5 percent higher systemic risk and about 7 percent higher bank-specific tail risk than other banks. On the other hand, the systemic risk of banks that are creating high levels of liquidity is approximately 4 percent lower and also their standalone tail risk is decreased by about 5.5 percent. When *Systemic linkage* is used as the dependent variable, the signs of the liquidity creation dummy variables change. Broadly consistent with our main regressions in Table 4, the positive coefficient for *High LC* indicates that the systemic linkage of individual banks to severe systemic shocks is more strongly positive for banks that are among the highest liquidity creators in the economy. The estimates in Table 6 also suggest that the degree of systemic linkage is almost 7 percent lower for banks with *Total LC* in the bottom quintile. Overall, it can be concluded that the relation of liquidity creation to systemic risk and its two subcomponents is slightly stronger in magnitude for banks that create low levels of liquidity.

Table 6
High vs. low liquidity creation.

	Systemic risk Model (1)	Tail risk Model (2)	Systemic linkage Model (3)
Liquidity creation:			
Low LC	0.047**	0.070***	-0.069***
	(2.32)	(3.75)	(-2.95)
High LC	-0.039**	-0.055***	0.051**
	(-2.36)	(-3.81)	(2.40)
Control variables:			
Size	0.065*	-0.090***	0.403***
	(1.89)	(-3.06)	(9.14)
Capital ratio	-1.480***	-2.624***	3.182***
	(-3.03)	(-5.60)	(5.53)
Profitability	-5.177***	-5.872***	2.483***
	(-7.10)	(-8.35)	(2.83)
Deposits to assets	0.206	0.261*	-0.076
	(1.28)	(1.79)	(-0.40)
Non-interest income	-0.077	-0.063	-0.006
	(-1.26)	(-1.20)	(-0.09)
Non-performing loans	3.052***	2.317*	2.596
	(2.58)	(1.71)	(1.44)
Constant	-1.267**	1.698***	-5.907***
	(-2.33)	(3.68)	(-8.68)
No. of banks	472	472	472
No. of observations	13,265	13,265	13,265
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.36	0.52	0.36

The table reports the estimates of three alternative versions of Equation (6). The dependent variables are defined as follows: *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level, *Tail risk* is the natural logarithm of bank-specific tail risk, and *Systemic linkage* is the natural logarithm of systemic linkage of individual banks to severe shocks in the financial system. *High LC* is a dummy variable which equals one for banks with *Total LC* in the top quintile in a given quarter, and *Low LC* is a dummy variable which identifies banks with *Total LC* in the bottom quintile, and *Total LC* is total liquidity creation scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1st and 99th percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

3.4. The role of bank size

Consistent with the prior literature, our empirical findings indicate that larger banks are associated with higher systemic risk. Given that bank size also influences the level of liquidity creation (Berger and Bouwman, 2009) as well as banks' systemic importance, business models, product compositions, governance mechanism, and monitoring stringency, it is of interest to examine whether the linkage between liquidity creation and systemic risk is influenced by bank-size effects. For this purpose, we next divide our sample into small, medium-sized, and large banks, and then

Table 7
The role of bank size.

	Small banks	Large banks	Difference	
Panel A: Univariate tests				
Total LC	0.414	0.500	-0.086***	
Systemic risk	-0.213	0.089	-0.302***	
Tail risk	0.494	0.303	0.191***	
Systemic linkage	0.041	1.506	-1.465***	
Panel B: Regression results				
	Small banks Model (1)		Medium-sized banks Model (2)	Large banks Model (3)
Liquidity creation:				
Total LC	-0.427**		-0.225*	-0.379***
	(-2.24)		(-1.90)	(-3.27)
Control variables:				
Size	0.105		0.035	-0.046
	(1.37)		(0.82)	(-0.95)
Capital ratio	-3.210***		-0.068	0.253
	(-4.29)		(-0.11)	(0.24)
Profitability	-3.508***		-4.923***	-7.204***
	(-3.48)		(-4.94)	(-4.58)
Deposits to assets	0.070		0.389**	-0.313
	(0.24)		(2.47)	(-1.16)
Non-interest income	-0.136		0.028	0.015
	(-0.81)		(0.54)	(0.31)
Non-performing loans	2.843		-0.665	3.370**
	(1.32)		(-0.65)	(2.35)
Constant	-1.502		-0.847	1.205
	(-1.34)		(-1.31)	(1.30)
No. of banks	313		208	61
No. of observations	6,313		5,559	1,393
Bank fixed-effects	Yes		Yes	Yes
Time fixed-effects	Yes		Yes	Yes
Adjusted R^2	0.47		0.43	0.35

Panel A reports the means and mean differences in *Total LC*, *Systemic risk*, *Tail risk*, and *Systemic linkage* between small and large banks and the results of *t*-tests for differences in the means. Panel B reports the estimates of Equation (6) based on subsamples of small, medium-sized, and large banks. Banks with total assets exceeding $20 billion are classified as large banks, banks with total assets between $2 billion and $20 billion as medium-sized banks, and banks with total assets below $2 billion as small banks. *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level and *Total LC* is total liquidity creation scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1st and 99th percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

examine the relationship between bank liquidity creation and systemic risk in each size category. Banks with total assets exceeding $20 billion are classified as large banks, banks with total assets between $2 billion and $20 billion as medium-sized banks, and banks with total assets below $2 billion as small banks.

Panel A of Table 7 presents the mean differences in *Total LC, Systemic risk, Tail risk*, and *Systemic linkage* between small and large banks and the results of *t*-tests for differences in the means. The univariate tests demonstrate that larger banks create significantly more liquidity, have higher systemic risk, are more interconnected with the financial system, and have lower bank-specific tail risk than smaller banks.

Panel B of Table 7 reports the estimation results of Equation (6) based on the subsamples of small, medium-sized, and large banks. The adjusted R^2s of these regressions range from 35 percent to 47 percent, being highest for the small bank subsample and lowest for the large banks. As shown in Panel B, the estimated coefficients for *Total LC* are negative and statistically significant in all three models, indicating that liquidity creation is negatively associated with systemic risk regardless of bank size. Nevertheless, bank size seems to influence the strength of the linkage; our estimates suggest that a one standard deviation increase in liquidity creation decreases the systemic risk of small and large banks by over 5 percent whereas the corresponding reduction is only 3.1 percent for medium-sized banks.

3.5. The role of bank funding structure

The process of liquidity creation essentially involves the transformation of liquid deposits into illiquid assets. At the same time, the level of deposit funding is an important determinant of systemic risk (see e.g, Mayordomo et al., 2014; Iqbal et al., 2015; and Van Oordt and Zhou, 2019a). Previous studies have documented that systemic risk is generally lower for banks that have a more traditional business model in which lending activities are mostly funded with deposits. Therefore, it is of interest to examine whether bank funding structure potentially influences the link between liquidity creation and systemic risk.

As the next step of our analysis, we split our sample into three subsamples based on the amount of deposits relative to total assets. Banks with deposits-to-assets ratios in the bottom and the top quintiles are regarded as the banks with the least and the most traditional funding structures, respectively, and the banks in the middle quintiles can be considered to have non-distinctive fund-

Table 8
The role of bank funding structure.

	Low deposits to assets ratio Model (1)	Medium deposits to assets ratio Model (2)	High deposits to assets ratio Model (3)
Liquidity creation:			
Total LC	-0.593***	-0.344***	-0.266
	(-3.70)	(-2.60)	(-1.16)
Control variables:			
Size	-0.008	0.123***	0.125
	(-0.12)	(3.21)	(1.37)
Capital ratio	1.263	-0.857	-4.176***
	(1.39)	(-1.63)	(-3.23)
Profitability	-8.741***	-5.638***	-1.168
	(-4.56)	(-6.33)	(-1.13)
Deposits to assets	-0.196	0.524***	0.459
	(-0.85)	(2.68)	(0.85)
Non-interest income	0.080	-0.115	-0.145
	(1.19)	(-1.27)	(-1.28)
Non-performing loans	7.191**	-0.743	4.018**
	(2.40)	(-0.83)	(2.22)
Constant	0.082	-2.193***	-2.056
	(0.08)	(-3.74)	(-1.58)
No. of banks	209	408	229
No. of observations	2,734	8,068	2,463
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.33	0.41	0.42

The table reports the estimates of three alternative versions of Equation (6) based on three funding structure subsamples. Banks with deposits-to-assets ratio in the bottom and the top quintiles are regarded as the banks with the least and the most traditional funding structures, respectively, and the banks in the middle quintiles are banks with non-distinctive funding profiles. *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level and *Total LC* is total liquidity creation scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1st and 99th percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

ing profiles. Table 8 reports the regression results based on the three funding structure subsamples. The adjusted R^2s of these regressions range from 33 percent to 42 percent, being lowest for banks with the least traditional funding profile and highest for the most traditional banks.

The estimates in Table 8 indicate that the linkage between liquidity creation and systemic risk is influenced by bank funding structure. Specifically, the estimated coefficients for *Total LC* are negative and statistically highly significant when the regressions are estimated using banks with lowest and medium levels of deposit funding while being insignificant in the subsample of banks with the most traditional funding structure. These regression results suggest that the documented negative linkage between liquidity creation and systemic risk is more pertained to banks with lower deposits-to-assets ratios. The strong negative association implies that a decrease in liquidity creation increases systemic risk most strongly for banks that rely more on nontraditional funding sources for their lending business. The magnitudes of the estimated coefficients suggest that a one standard deviation decrease in *Total LC* increases *Systemic risk* of banks with the least traditional funding structure by about 8.1 percent, while the corresponding increase in *Systemic risk* is 4.7 percent for banks with a more standard funding profile.

3.6. The role of bank capital structure

The level of equity capital is the main variable of interest for banking supervisors and regulators. As documented e.g. by Acharya and Thakor (2016), Van Oordt and Zhou (2019a), and Berger et al. (2020), banks with lower capital ratios are associated with higher systemic risk. Moreover, the findings of Zheng et al. (2019) suggest that the amount of equity capital influences the negative relationship between liquidity creation and the likelihood of bank failure. Therefore, we proceed by examining whether the linkage between liquidity creation and systemic risk is conditional on banks' capital structure. We divide our sample into three subsamples based on the ratio of equity capital to total assets. Banks with capital ratios in the bottom and the top quintiles are regarded as the banks with the weakest and the strongest capital positions, respectively, and the banks in the middle quintiles are considered to have non-distinctive capital ratios.

The regression results based on the three capital structure subsamples are presented in Table 9. As can be seen from the table, the adjusted R^2s of the regressions vary between 32 and 47 percent. The estimated coefficients for *Total LC* are negative and statistically highly significant when the regressions are estimated using subsamples of banks with low and medium capital ratios, and for banks with the strongest capital buffers, the coefficient estimate is insignificant. Thus, our estimates suggest that the amount of equity capital influences the linkage between liquidity creation and systemic risk. A decrease in liquidity creation increases systemic risk most strongly for banks that have the weakest capital buffers, and for these banks, a one standard deviation decrease in *Total LC* increases *Systemic risk* by about 7 percent.

3.7. Alternative measures of systemic risk

Given that different systemic risk metrics may provide different assessments of systemic risk (see e.g., Kleinow et al., 2017), we next utilize an alternative market-based approach to estimate systemic risk at the individual bank level. Specifically, in order to ascertain the robustness of our empirical findings, we use the marginal expected shortfall (*MES*) and systemic risk (*SRISK*) proposed by Acharya et al. (2012,2017) and Brownlees and En-

Table 9
The role of bank capital structure.

	Low capital ratio Model (1)	Medium capital ratio Model (2)	High capital ratio Model (3)
Liquidity creation:			
Total LC	-0.489**	-0.292**	-0.231
	(-2.21)	(-2.36)	(-1.09)
Control variables:			
Size	-0.066	0.101**	0.189***
	(-0.70)	(2.22)	(2.97)
Capital ratio	-3.220***	-1.276*	-0.049
	(-3.06)	(-1.80)	(-0.07)
Profitability	-2.981***	-5.495***	-4.786**
	(-3.19)	(-5.12)	(-2.43)
Deposits to assets	0.613**	0.256	-0.210
	(2.08)	(1.37)	(-0.59)
Non-interest income	0.158	-0.154**	-0.047
	(1.51)	(-1.99)	(-0.32)
Non-performing loans	9.553***	4.936***	0.113
	(3.03)	(3.12)	(0.06)
Constant	0.482	-1.709**	-2.874***
	(0.34)	(-2.38)	(-2.82)
No. of banks	260	419	209
No. of observations	2,363	8,019	2,883
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.47	0.38	0.32

The table reports the estimates of three alternative versions of Equation (6) based on three capital structure subsamples. Banks with capital ratios in the bottom and the top quintiles are regarded as the banks with the weakest and stongest capital positions, respectively, and the banks in the middle quintiles are banks with non-distinctive capital structures. *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level and *Total LC* is total liquidity creation scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1st and 99th percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

gle (2017) as alternative measures to gauge systemic risk at the individual bank level. *MES* is defined as the expected daily decrease in the market value of equity of an individual bank when the aggregate financial sector declines by more than 5 percent. *SRISK*, in turn, is the expected capital shortage of a bank amidst a financial crisis computed based on *MES* and the bank's capital structure under the assumption that a bank needs at least 8 percent of equity capital relative to its total assets.[7] We use daily stock price data to estimate *MES* and *SRISK* for each bank and each quarter, and we then re-estimate different versions of Equation (6) with *MES* and *SRISK* as the dependent variables.

The regression results with *MES* and *SRISK* as the dependent variables are presented in Table 10. Overall, the estimates of these regressions are very similar to the results reported in Table 3. The coefficient estimates for the different liquidity creation measures are negative and statistically significant, with the only exception being the insignificant coefficients for *Off-Bs LC* in Models 2 and 5. Thus, consistent with our main regressions, the results provide evidence that liquidity creation and especially on-balance sheet liquidity creation on both the asset and liability sides of the balance sheet decreases systemic risk at the individual bank level. With respect to the control variables, the estimates in Table 10 are broadly consistent with our main regressions. Specifically, *MES* and *SRISK* are significantly positively associated with *Size* and *Non-performing loans*, while being negatively related to *Profitability*.

[7] See Acharya et al. (2012,2017), and Brownlees and Engle (2017) for a more detailed description of *MES* and *SRISK*.

3.8. Other additional tests

We perform a number of additional tests to ascertain the robustness of our results. First, given that our sample period includes the very exceptional crisis years 2007-2009, we examine whether and how our results are influenced by the global financial crisis. For this purpose, we re-estimate the regressions using three truncated samples: (i) the pre-crisis period from 2004 to the second quarter of 2007, (ii) the financial crisis period from the third quarter of 2007 to the end of 2009, and (iii) the post-crisis years 2010-2016. The estimates of the regressions based on the truncated samples are reported in Table 11. As can be noted from the table, the estimates indicate that liquidity creation is negatively associated with systemic risk at the individual bank level in all three subperiods. Similar to Tables 3 and 4, the coefficients for *Total LC* are negative and significant in all three subperiods in the regressions with *Systemic risk* and *Tail risk* as the dependent variables. The magnitudes of the coefficient estimates suggest that the negative linkage between bank liquidity creation and systemic risk was stronger during the financial crisis. However, the subperiod estimates also indicate that the positive association between liquidity creation and systemic linkage documented in Table 4 mostly pertains to the crisis period as the coefficients for *Total LC* are insignificant in the pre-crisis and post-crisis periods.

Second, as a further test related to the global financial crisis, we estimate regressions in which we include a financial crisis dummy which takes the value of one from the third quarter of 2007 to the end of 2009. Given that liquidity creation declined substantially for most banks during the crisis years, we use the quarterly dollar change in total liquidity creation and interactions of this

Table 10
Alternative measures of systemic risk.

		MES			SRISK	
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Liquidity creation:						
Total LC	-0.010**			-0.060***		
	(-2.28)			(-2.77)		
On-Bs LC		-0.013**			-0.040***	
		(-2.27)			(-2.95)	
Off-Bs LC		-0.001			-0.114	
		(-0.06)			(-1.49)	
Asset-side LC			-0.011*			-0.034*
			(-1.82)			(-1.76)
Liabilitity-side LC			-0.028**			-0.186***
			(-2.22)			(-4.38)
Control variables:						
Size	0.006***	0.006***	0.006***	0.013**	0.013**	0.012**
	(4.21)	(4.23)	(4.10)	(2.39)	(2.38)	(2.21)
Capital ratio	0.117***	0.117***	0.113***	-0.206	-0.211	-0.247
	(4.73)	(4.77)	(4.55)	(-1.12)	(-1.17)	(-1.38)
Profitability	-0.335***	-0.337***	-0.329***	-0.886*	-0.874*	-0.846*
	(-6.13)	(-6.18)	(-6.09)	(-1.93)	(-1.94)	(-1.82)
Deposits to assets	0.007	0.008	0.010	0.031	0.026	0.050
	(0.85)	(0.94)	(1.16)	(0.87)	(0.79)	(1.41)
Non-interest income	0.001	0.001	0.001	-0.017*	-0.016*	-0.014
	(0.33)	(0.31)	(0.42)	(-1.95)	(-1.92)	(-1.56)
Non-performing loans	0.243***	0.244***	0.240***	0.336	0.332	0.310
	(3.90)	(3.87)	(3.80)	(1.16)	(1.10)	(1.15)
Constant	-0.082***	-0.083***	-0.080***	-0.220**	-0.215**	-0.197**
	(-3.72)	(-3.75)	(-3.59)	(-2.33)	(-2.32)	(-2.12)
No. of banks	469	469	469	460	460	460
No. of observations	13,612	13,612	13,612	13,474	13,474	13,474
Bank fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.55	0.55	0.56	0.38	0.38	0.38

The table reports the estimates of alternative versions of Equation (6) based on two alternative systemic risk measures. The dependent variables *MES* and *SRISK* are the marginal expected shortfall and systemic risk proposed by Acharya et al. (2012,2017) and Brownlees and Engle (2017). The liquidity creation measures are defined as follows: *Total LC* is total liquidity creation scaled by total assets, *On-Bs LC* is the amount of liquidity created through on-balance sheet activities scaled by total assets, *Off-Bs LC* is the amount of liquidity created through off-balance sheet activities scaled by total assets, *Asset-side LC* is the amount of liquidity created on the asset side of the bank's balance sheet scaled by total assets, and *Liability-side LC* is the amount of liquidity created on the liability side of the bank's balance sheet scaled by total assets. The bank-specific control variables are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1st and 99th percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

variable with the crisis dummy as the test variables of interest. The estimates of these additional regressions (not tabulated) are broadly consistent with our main results and indicate that bank liquidity creation is negatively associated with *Systemic risk* and *Tail risk*.[8] Furthermore, the coefficient for the interaction variable *Total LC* × *Crisis* is also negative and statistically significant in the regression with *Tail risk* as the dependent variable, suggesting that the negative linkage between liquidity creation and bank-specific tail risk was stronger during the financial crisis. In the regression with *Systemic linkage* as the dependent variable, the coefficient estimates for *Total LC* and the interaction variable *Total LC* × *Crisis* are insignificant, while the coefficient for *Crisis* is positive and significant. Thus, it can be concluded from our additional tests related to the financial crisis that the positive association between liquidity creation and systemic linkage is less robust and is to some extent induced by the unusual market turmoil during 2007-2009.

Third, to ensure that our empirical findings are not driven by macroeconomic and market conditions that potentially affect bank-level decisions related to liquidity creation as well as the systemic risk of individual banks, we next estimate regressions in which we control for the monetary policy stance, stock market liquidity, and stock market uncertainty. Berger and Bouwman (2017) document that monetary policy influences bank liquidity creation, while the findings of Chatterjee (2015) and Brownlees and Engle (2017) indicate that stock market liquidity and volatility are related to both bank liquidity creation and systemic risk. Thus, we include the federal funds rate, the Pastor and Stambaugh (2003) liquidity measure, and the CBOE's VIX index as control variables in addition to the bank-specific attributes used as the controls in our main analysis. The estimates of these regressions (not tabulated) are very similar to the estimates reported in Tables 3 and 4. Most importantly, the coefficient estimates for *Total LC* have the same signs, are similar in magnitude, and have the same significance levels as in our main regressions. The regression results also indicate that systemic risk and its two subcomponents are negatively associated with the monetary policy target rate and market liquidity while being positively related to the VIX index.

Fourth, we re-estimate *Systemic risk*, *Tail risk*, and *Systemic linkage* for each bank and each quarter by using a longer estimation window of four years. We then re-estimate alternative versions of Equation (6) by using the new systemic risk estimates as the dependent variables. The estimates of these regressions (not tabulated) are similar to the results reported in Tables 3 and 4. In particular, the estimated coefficients for *Total LC* are negative and highly significant in the regressions with *Systemic risk* and *Tail risk*

[8] For brevity, the results of the remaining additional tests are only described in the text. Tabulated results are available from the authors.

Table 11
Liquidity creation and systemic risk in different subperiods.

	Systemic risk Model (1)	Tail risk Model (2)	Systemic linkage Model (3)
Panel A: Pre-crisis period			
Liquidity creation:			
Total LC	-0.314*	-0.260**	-0.118
	(-1.66)	(-1.96)	(-0.49)
Control variables	Yes	Yes	Yes
No. of banks	401	401	401
No. of observations	4,143	4,143	4,143
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.54	0.67	0.41
Panel B: Crisis period			
	Systemic risk Model (1)	Tail risk Model (2)	Systemic linkage Model (3)
Liquidity creation:			
Total LC	-0.701***	-0.860***	0.525*
	(-3.35)	(-5.54)	(1.73)
Control variables	Yes	Yes	Yes
No. of banks	334	334	334
No. of observations	2,842	2,842	2,842
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.21	0.50	0.27
Panel C: Post-crisis period			
	Systemic risk Model (1)	Tail risk Model (2)	Systemic linkage Model (3)
Liquidity creation:			
Total LC	-0.291*	-0.354***	0.247
	(-1.94)	(-2.60)	(1.27)
Control variables	Yes	Yes	Yes
No. of banks	326	326	326
No. of observations	6,280	6,280	6,280
Bank fixed-effects	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes
Adjusted R^2	0.24	0.37	0.21

The table reports the estimates of alternative versions of Equation (6) based on three truncated samples: (i) the pre-crisis period from 2004 to the second quarter of 2007, (ii) the financial crisis period from the third quarter of 2007 to the end of 2009, and (iii) the post-crisis years 2010-2016. The dependent variables are defined as follows: *Systemic risk* is the natural logarithm of systemic risk measure at the individual bank level, *Tail risk* is the natural logarithm of bank-specific tail risk, and *Systemic linkage* is the natural logarithm of systemic linkage of individual banks to severe shocks in the financial system. *Total LC* is total liquidity creation scaled by total assets. The bank-specific control variables used in the regressions are defined as follows: *Size* is the natural logarithm of total assets, *Capital ratio* is the ratio of equity capital to total assets, *Profitability* is measured with return on assets which is calculated as the ratio of net income to total assets, *Deposits to assets* is the amount of total deposits divided by total assets, *Non-interest income* is the ratio of non-interest income to interest income, and *Non-performing loans* is the ratio of non-performing loans to total loans. All variables are trimmed at the 1^{st} and 99^{th} percentiles. The *t*-statistics (in parentheses) are based on robust standard errors which are adjusted for heteroskedasticity and are clustered by bank. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

as the dependent variables, while being positive and significant in the regression with *Systemic linkage* as the dependent variable.

Fifth, given that the amount of liquidity creation is largely driven by bank size, we have scaled liquidity creation by total assets in our empirical tests. To examine whether our findings are robust to alternative variable definitions, we replace *Total LC* first by the quarterly change in the dollar amount of liquidity creation and then by the quarterly logarithmic difference in liquidity creation. The estimated coefficient for the change in liquidity creation is negative and statistically significant at the 5 percent level and the coefficient for the logarithmic difference is negative and significant at the 1 percent level in the regressions with *Systemic risk* as the dependent variable (not tabulated). Thus, consistent with our main regressions, the estimates of the change regressions suggest that increasing liquidity creation decreases systemic risk at the individual bank level.

Finally, we examine the sensitivity of our results to the lag structure used in the estimations. In our main regressions, the independent variables have been lagged by one quarter in order to mitigate potential problems with simultaneity. As an additional robustness check, we re-estimate Equation (6) using independent variables lagged by one year. The estimation results (not tabulated) are very similar to our main regressions, and therefore, provide further evidence that bank liquidity creation is negatively related to systemic risk. The estimated coefficient for *Total LC* indicates that a one standard deviation increase in liquidity creation is associated with a 3 percent decrease in systemic risk. Interestingly, the coefficients for the control variables become more significant and slightly larger in magnitude when one-year lags instead of one-quarter lags are used in the regressions.

Collectively, our additional tests suggest that the results documented in this paper are robust to different measures of systemic risk and liquidity creation and many alternative model specifications. Our main results also hold when different samples and different sets of control variables are used in the regressions. Therefore, the robustness checks provide strong additional evidence that liquidity creation decreases systemic risk at the individual bank level.

4. Conclusions

This paper studies the relationship between bank liquidity creation and systemic risk. The process of liquidity creation by transforming liquid deposits into illiquid assets is a focal task of banks in the economy. While liquidity creation is a necessity for the financial system, it makes banks less liquid and exposes them to different types of risks. The systemic risk of financial institutions has received considerable supervisory and regulatory attention over the last ten years in the aftermath of the global financial crisis of 2008-2009. The crisis demonstrated how risk-taking of individual financial institutions may have severe adverse consequences on the financial system and global financial stability. If liquidity creation may potentially increase the stand-alone risk of banks, how does it affect systemic risk at the individual bank level? In this paper, we address this question by empirically examining the linkage between bank liquidity creation and systemic risk.

In our empirical analysis, we use quarterly data on publicly traded U.S. bank holding companies over the period 2003–2016. Following the prior literature, we utilize the three-step procedure of Berger and Bouwman (2009) to measure the level of liquidity creation of individual banks. To gauge the systemic risk of individual banks, we employ the novel systemic risk measure developed by Van Oordt and Zhou (2019a). The key advantage of this approach is that it enables us to decompose the systemic risk of individual banks into bank-specific tail risk and systemic linkage to severe shocks in the financial system.

We find that bank liquidity creation decreases systemic risk after controlling for bank size, asset risk, income and funding structure, and other bank-specific attributes. Furthermore, our results demonstrate that liquidity creation both through the bank's on-balance sheet and off-balance sheet activities as well as liquidity creation on both the asset and liability sides of the balance sheet are negatively associated with the level of systemic risk. After decomposing systemic risk into bank-specific tail risk and systemic linkage, we find that the riskiness of individual banks is strongly negatively linked to liquidity creation. Nevertheless, our results also indicate that increasing liquidity creation may strengthen the systemic linkage of individual banks to severe shocks in the financial system. We conduct a number of additional tests that suggest that our empirical findings are robust to alternative variable definitions, different model specifications, and the inclusion of additional controls. These tests indicate, among other things, that the strength of the linkage between liquidity creation and systemic risk is influenced by bank size, funding structure, and the amount of equity capital.

Overall, our empirical findings demonstrate that the level of bank liquidity creation may have important implications for financial stability and micro- as well as macro-prudential supervision and regulation of financial institutions. The results documented in this paper suggest that liquidity creation may decrease rather than increase risk at the individual bank level even though the process of liquidity creation is inherently risky and makes the banks less liquid. Thus, from a prudential policy and liquidity regulation perspective, higher liquidity creation by individual banks may be more desirable to the extent that it decreases the systemic risk of individual banks as well as bank-specific tail risk. Nevertheless, given that increasing liquidity creation can strengthen the systemic linkage of individual banks to shocks in the system, excessive liquidity creation may potentially heighten the collective fragility of financial institutions during adverse market conditions. Our results also indicate that aggregate liquidity creation in the system and liquidity creation at the individual bank level may have opposite effects on systemic risk. Consequently, when monitoring systemic risk, it is important to emphasize the complementary roles of micro- and macro-prudential supervision and regulation. In general, our findings suggest that more rigorous monitoring of bank liquidity creation can be a useful supervisory tool to promote the stability of the financial system.

Appendix 1. Construction of the Berger and Bouwman (2009) liquidity creation measures

Category measure Assets Illiquid assets (+1/2)	Semiliquid assets (0)	Liquid assets (-1/2)
Commercial real estate loans	Residential real estate loans	Cash and due from other institutions
Loans to finance agricultural production	Consumer loans	All securities (regardless of maturity)
Commercial and industrial loans	Loans to depository institutions	Trading assets
Other loans and lease financing receivables	Loans to state and local governments	Federal fund sold
Other real estate owned	Loans to foreign governments	
Customers' liability on bankers' acceptances		
Investment in unconsolidated subsidiaries		
Intangible assets		
Premises		
Other assets		
Liabilities and equity		
Liquid liabilities (+1/2)	Semiliquid liabilities (0)	Illiquid liabilities and equity (-1/2)
Transaction deposits	Time deposits	Bank's liabilities on banker's acceptances
Saving deposits	Other borrowed money	Subordinated debt
Overnight federal funds purchased		Other liabilities
Trading liabilities		Equity
Off-balance sheet derivatives		
		Liquid derivatives (-1/2)
		Interest rate derivatives
		Foreign exchange derivatives
		Equity and commodity derivatives

CRediT authorship contribution statement

Denis Davydov: Conceptualization, Data curation, Formal analysis, Writing - review & editing. **Sami Vähämaa:** Conceptualization, Project administration, Supervision, Writing - original draft, Writing - review & editing. **Sara Yasar:** Conceptualization, Data curation, Formal analysis, Writing - original draft.

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Bank Liquidity Creation and Technological Innovation[☆]

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Abstract

This paper examines the association between bank liquidity creation and technological innovation. Using a comprehensive measure of bank output, I find that bank liquidity creation stymies technological innovation, measured by patent-based criteria. This is robust to using the difference-in-differences approach, instrumental variable approach, and several other robustness checks. Further analysis reveals that small banks are more likely to promote firm innovation, and bank liquidity creation enhances innovation by firms that have above-median asset tangibility. Overall, the results in this paper provide important insight into the prospect of banking and finance and suggest that the role of banks in promoting innovation is limited during the transition to the knowledge-based economy.

JEL classification: G20, G21, G28, G32, O31
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1. Introduction

A preeminent role of banks in the economy is to provide liquidity by financing long-term illiquid assets with short-term liquid liabilities (Bryant, 1980; Diamond and Dybvig, 1983). By offering liquid deposits to customers and choosing a mixture of liquid and illiquid investments while facilitating long-term investments with high returns, banks can provide liquidity to the economy. In general, previous studies have documented that bank liquidity creation is positively associated with economic growth (see e.g., Fidrmuc, Fungacova, and Weil, 2015; Berger and Sedunov, 2017; Beck, Döttling, Lambert, and Van Dijk, 2020). However, there is very little known about whether and how bank liquidity creation, as the main function of banks in the economy, enhances or stymies innovation – the main channel through which financial function affects economic growth. Thus, this paper examines first and foremost how banks affect technological progress by focusing on the role of bank liquidity creation.

Prior studies indicate that financial intermediation has a crucial role in promoting or hampering long-term economic growth depending on the evolutionary process generating innovation (see e.g., Dosi, 1988; Fagiolo et al., 2020). While a well-functioning financial system may improve the probability of successful innovation and thus promote economic growth (see e.g., Schumpeter, 1911; King and Levine, 1993b), an increase in banking credit may also dampen economic growth (see e.g., Kaminsky and Reinhart,1999; Schularick and Taylor, 2012). A recent study by Beck et al. (2020) shows that the positive effect of bank liquidity creation on growth is driven by tangible rather than intangible investment. Given that innovation is the main channel through which financial function may affect economic growth (Solow, 1957), the role of banks in promoting or hampering innovation is still debatable. Therefore, this paper attempts to fill the gap in the finance-growth nexus literature by presenting the first empirical examination of whether bank liquidity creation affects innovation output as measured by patent-based metrics.

A key difference between the current study and the previous literature is that I focus on liquidity creation as one of the most important economic roles of banks. A vast majority of empirical studies use bank credit which only considers a part of banks' function, and it cannot reflect the total bank output in the economy.[1] Banks' off-balance sheet activities account for about fifty percent of all liquidity creation in the US (Berger and Bouwman, 2009), and thus neglecting off-balance sheet activities may fail to capture a major part of bank output. Therefore, the desirable feature of a liquidity creation measure over other size-based measures of banking sector development is that it accounts for both on- and off-balance sheet banking activities. Since innovation is inherently risky and has limited collateral values, the liquidity-creation activity of banks could drive banks' decisions to finance innovative projects. For example, consider two different types of banks, namely a fully equity-funded bank and a narrow bank. The fully equity-funded bank can make long-term loans and increase the overall size of the banking sector by granting bank credit. Nonetheless, these types of banks cannot create liquidity to the economy and could be substituted by similar banks. A narrow bank that takes deposits and invests the money in interest-bearing reserves can increase the overall size of the banking sector by offering demand deposits. However, similar to fully equity-funded banks, these types of banks cannot also create liquidity and their service can be replaced by other payment infrastructure such as utilizing digital

[1] Some papers have used branch density or the ratio of liquid liabilities to GDP as a measure of financial development (see e.g., King and Levine 1997a; Benfratello, Schiantarelli, and Sembenelli, 2008). However, liquid liabilities may not reflect the total bank output, and are also part of liquidity creation measure.

money. Therefore, the liquidity-creation activity of banks can better capture the impact of bank activities on innovation output.

In addition, the existing evidence on the relationship between banking sector development and innovation typically focuses on a sized-based measure of banking development such as private credit to GDP. Using a comprehensive measure of liquidity creation developed by Berger and Bouwman (2009) tackles the problem of using such basic and rough proxies. Specifically, this measure takes into account all bank's balance sheet activities such as assets, liabilities, equity, and bank's off-balance sheet activities. Each component of liquidity creation such as bank loans, transaction deposits, off-balance sheet derivatives, and guarantees, has different theoretically-driven weights based on ease, cost, and time for customers to obtain liquid funds from the bank. In this regard, I add to the finance-growth nexus literature that examines the role of the banking sector's development on technological innovation.

To examine the linkage between bank liquidity creation and technological innovation, I use US state-level data. In particular, I use annual state-level data on bank liquidity creation and innovation output from 1984 to 2006. Following prior studies on bank liquidity creation, I use the three-step procedure of Berger and Bouwman (2009) to measure liquidity provision by banks. Specifically, I use the measure of liquidity creation which incorporates all bank on- and off-balance sheet activities (*Total LC*), the measure which only includes on-balance sheet activities (*LC-OnBS*), and also the measure which only includes off-balance sheet activities (*LC-OffBS*). Following the existing innovation literature, I use patents and citations as measures of innovation output.

By way of preview, I find that bank liquidity creation is negatively associated with technological innovation. This relation is robust to controlling for state-level conditioning variables, banking environment and regulation, state fixed-effects, and year fixed-effects. To alleviate the endogeneity concern, I first employ the staggered timing of the intrastate branching deregulation across states to identify the changes in bank liquidity creation. The results show that the removal of the intrastate branching restrictions decreases firm innovation output more than those states which have not yet passed the removal of restrictions. Following Berger and Sedunov (2017), I also utilize bank capital as an instrumental variable and conduct the two-stage least squares regression, and the results are the same when using the instrumental variable approach. My findings also hold robust after controlling for any potentially confounding demand factors and several other robustness checks. Broadly consistent with the negative relation between banking sector development and innovation documented by Atanassov, Nanda, and Seru (2007), Cornaggia, Mao, Tian, and Wolfe (2015), and Xin, Sun, Zhang, and Liu (2019), I find strong evidence that bank liquidity creation decreases rather than increases innovation output.[2] In additional tests, I document that the observed negative relationship is mainly driven by the finance industry.

While a recent study by Beck et al. (2020) documents that the positive effect of bank liquidity creation on growth is driven by tangible rather than intangible investment, I contribute to the literature by showing that bank liquidity creation is negatively associated with innovation output. Furthermore, I complement and extend the work of Hombert and Matray (2017), and Beck et al. (2020) by exploring whether banks support innovation output by firms with more tangible assets. Broadly consistent with the findings of Hombert and Matray (2017), and Beck et al. (2020), the

[2] Cornaggia et al. (2015) document that banking development via interstate branching deregulation has a negative impact on innovation by public firms, while Atanassov et al. (2007) and Xin et al. (2019) find that relationship-based financing such as bank debt is negatively related to innovation.

results indicate that bank liquidity creation enhances innovation only by those firms that have higher tangible assets. My findings also suggest an important non-linearity in the form of asymmetry in the relation between bank liquidity creation and innovation; bank liquidity creation hinders innovation during economic expansions but not economic recessions. Collectively, my analysis provides new insight into the debate about the structure of financial systems (i.e., market-oriented financial systems and bank-oriented financial systems) by exploring the effect of bank liquidity creation on innovation over business cycle fluctuations (Gambacorta, Yang, and Tsatsaronis, 2014; Allen, Gu, and Kowalewski, 2019).

Overall, the findings in this paper stress the limited role of banks in promoting innovation during the transition to the knowledge-based economy and have important implications. Given that bank liquidity creation stymies innovation, more stringent macro-prudential regulation on bank liquidity could have a positive impact not only on financial stability but also on the long-run performance of the economy. Second, government policies toward financial systems may have an important effect on innovative activities and long-run growth. Therefore, authorities and banking supervisors should pay closer attention to total bank output and the size of the banking sector. Also, they should improve the measures that strengthen the quality of finance. Even though previous researchers find that bank liquidity creation is one of the determinants of economic growth, if liquidity creation is negatively associated with innovation in a particular situation, then other growth-enhancing strategies need to be implemented by authorities to maintain long-run economic benefits.

The rest of the paper proceeds as follows. Section 2 discusses how this paper is related to the existing literature. Section 3 describes the data and variable constructions. Section 4 presents the methodology, baseline results, and other empirical findings. Section 5 presents the robustness tests. Finally, the last section summarizes the findings and concludes the paper.

2. The relevant literature discussion

Previous theoretical and empirical studies have contrasting views on the role of the financial system on technological innovation. For example, the theoretical models of King and Levine (1993b) and Laeven, Levine, and Michalopoulos (2015) show that the financial system plays an essential role in promoting technological innovation. On the other hand, Aghion and Tirole (1994) suggest that the moral hazard problem and asymmetric information are key impediments to corporate innovation because outcomes of innovative projects are unpredictable and difficult to contract ex-ante. In addition, Zingales and Rajan (2003) argue that bank financing may discourage firms from investing in innovative projects under relationship lending because novel projects involve large ex-ante uncertainty that is not desirable for banks to collect information. In this regard, bank financing has a negative impact on innovation.

Empirical studies also offer conflicting predictions that mirror the theoretical ambiguity. For instance, Amore, Schneider, and Žaldokas (2013) find that interstate banking deregulations foster corporate innovation. On the other hand, Cornaggia et al., (2015) exploit interstate banking deregulation to test the effect of banking competition on technological innovation and find that banking competition has a negative impact on innovation by public firms. Another strand of the literature shows that relationship-based bank financing and bank interventions are negatively associated with innovation output (see e.g., Atanassov et al., 2007; and Gu et al., 2017). Hsu, Tian, and Xu (2014) provide cross-country evidence suggesting that credit market development has a negative effect on industries' innovation. More recently, Xin et al. (2019) also find that debt financing decreases radical innovation in China.

The theoretical model of Diamond and Dybvig (1983) highlights that banks can offer liquid deposits to investors and undertake a mixture of liquid, low return investments to satisfy demands on deposits and illiquid, high-return investments. By offering liquid deposits to customers and choosing a mixture of liquid and illiquid investments while facilitating long-term investments with high returns, banks can provide liquidity to the economy. Technological innovation is characterized by asymmetrical information, moral hazard problems, long-run monitoring, and commitment of capital (Akerlof, 1970; and Hall, 2002), and thus extensive rigid finance of illiquid and risky innovative projects may expose the economy to adverse shocks that might take down the financial intermediaries. I advance this line of inquiry as to how financial intermediaries affect innovation by using a comprehensive measure of bank output in the economy.

My paper builds upon two recent strands of literature. First, it is related to the emerging literature on finance and innovation.[3] Few recent papers examine the impact of credit market development on technological innovation. For example, Hombert and Matray (2017) show that intrastate banking deregulation decreases the number of innovative firms, especially those that rely on relationship lending such as small firms. In contrast, Benfratello et al. (2008) find that local banking development has a positive impact on process innovation, but it does not have a robust impact on product innovation. Laeven et al. (2015) show that technological innovation and

[3] Some recent studies examine the link between innovation and market characteristics (see e.g., Tian and Wang, 2014; Acharya, Baghai, and Subramanian, 2013; Acharya and Subramanian, 2009; and Aghion, Bloom, Blundell, Griffith, and Howitt, 2005) as well as firm characteristics (see e.g., Fang, Tian, and Tice, 2014; Aghion, Van Reenen, and Zingales, 2013).

economic growth eventually stop without financial innovations that enhance the screening of technological entrepreneurs.

Second, this paper is also related to the burgeoning literature on bank liquidity creation. The role of bank liquidity creation for the macroeconomy and economic growth is empirically examined by Fidrmuc et al. (2015), Berger and Sedunov (2017), and Davydov, Fungacova, and Weill (2018). These studies show that liquidity creation is positively related to economic output as well as business cycle fluctuations. Horváth, Seidler, and Weill (2014), Berger, Bouwman, Kick, and Schaeck (2016), Diaz and Huang (2017), Fungacova, Weill, and Zhou (2017) examine how liquidity creation is affected by bank-specific attributes, regulatory environment, and policy actions. The findings indicate the level of liquidity creation is higher for banks with lower capital ratios and stronger corporate governance mechanisms (Horváth et al., 2014; Diaz and Huang, 2017). Furthermore, bank liquidity creation is affected by regulatory interventions, bailouts, and deposit insurance systems (Berger et al., 2016; Fungacova et al., 2017), but is largely unaffected by monetary policy (Berger and Bouwman, 2017). A recent study by Davydov, Vähämaa, and Yasar (2021) also examines the association between bank liquidity creation and systemic risk. They find that bank liquidity creation increases the systemic linkage of individual banks to severe shocks in the financial system, but at the same time, it decreases the riskiness of individual banks.

The association between bank liquidity creation and technological innovation might be unclear ex-ante. Because bank liquidity creation is positively associated with GDP, the provision of liquidity might also be positively associated with technological innovation, as technological innovation is the main driver of economic growth due to its effect on productivity growth and aggregate growth. However, if high liquidity creation is associated with financial crises and financial system instability as documented by Acharya and Naqvi (2012) and Berger and

Bouwman (2017), liquidity creation may be associated with lower technological innovation since it can dampen long-run growth. Thus, how bank liquidity creation affects corporate innovation is ultimately an empirical question.

3. Data

3.1. Measuring innovation

To measure innovation activities, patent and patent citation data are collected from the NBER Patent and Citation database created by Hall, Jaffe, and Trajtenberg (2001) for the period 1984-2006.[4] The database provides the annual information on patent assignee names, the number of patents, the number of citations for each patent, a patent's application year, a patent's grant year, etc. Following Hall et al. (2001), and Grilinches, Pakes, and Hall (1986), a patent's application year is used instead of its grant year since the actual time of innovation is better captured by the application year.

I construct two measures of a firm's innovation output based on the information available in the NBER database. The first measure employed in this study is the number of patent applications a firm files in a year that are eventually granted. Even though it is straightforward to calculate, the first measure cannot differ groundbreaking innovations from incremental technological

[4] A vast majority of studies in the existing innovation literature use the NBER Patent and Citation database (see e.g., Hirshleifer, Low,and Teoh, 2012; Amore, et al., 2013; He and Tian, 2013; Hirshleifer, Hsu, and Li; 2013; Bena and Li, 2014; Fang et al. 2014; Chang, Fu, Low, and Zhang, 2015; Acharya and Xu, 2017; Cornaggia et al., 2015; Hombert and Matray, 2017; Nguyen, 2018; Entezarkheir, 2019).

discoveries (Trajtenberg, 1990). As a second measure, I use the citation count each patent receives in subsequent years to further assess a patent's influence. While the number of citations captures the economic importance of innovation output, the number of patents captures the quantity of innovation output. Following the innovation literature, I use both measures of innovation output generated in the three subsequent years to reflect the long-term nature of investment in innovation. This approach also mitigates the impact of idiosyncratic shocks which can distort innovation productivity in any year.

Following the innovation literature, the truncation bias observed in the two measures of innovation output is corrected by employing the "quasi-structural" approach proposed by Hall et al. (2001). As a robustness check, I adjust the truncation bias for the two innovation measures by employing the "fixed-effect" approach proposed by Hall et al. (2001). The first truncation bias arises as patents appear in the database only after they are granted. Therefore, there is a gradual decrease in the number of patents as one approaches the last few years in the sample period. The second truncation bias is related to the citations as patents keep receiving citations over a long period. However, the database stops in 2006. Table 1 reports the definitions and sources for the variables used in the analysis. The sample consists of annual state-level observations between 1984 and 2006.

[Insert Table 1 here]

To match the patent database to the firm's GVKEY, I merge the patent data with Compustat data using the bridge file provided by the NBER database. Following the innovation literature, for companies that have no patent information available in the NBER database, I set the number of patents to zero. I drop assignees that are either universities, individuals, or governments.[5]

I use the natural logarithm of the two measures of innovation output due to the right-skewed distributions of patents and citations. Also, when I compute the natural logarithm, I add one to the actual values of patents and citations to avoid losing observations with zero patents and citations.

3.2. Measures of bank liquidity creation

For a long time, liquidity creation was only a theoretical concept (see e.g., Diamond and Dybvig, 1983; Holmstrom and Tirole, 1998; and Kashyap, Rajan, and Stein, 2002.), and thus it received little attention in prior empirical research. In 2009, Berger and Bouwman developed a comprehensive measure of bank output which is consistent with the financial intermediation theory. According to the modern theory of financial intermediation, banks can create liquidity on their balance sheets by financing relatively illiquid assets such as long-term loans with relatively liquid liabilities such as demand deposits (Bryant, 1980; and Diamond and Dybvig, 1983), and they can also create liquidity off their balance sheets through loan commitments and other kinds of claims such as standby letters of credit (Kashyap et al., 2002). Berger and Bouwman's liquidity creation measures are the weighted sum of the bank's all on- and off-balance sheet activities. To summarize briefly, positive weights are given to illiquid assets, and liquid liabilities, and negative weights are given to liquid assets, illiquid liabilities, and equity. The weights assigned to off-

[5] I use annual data, even though liquidity creation data are available quarterly. This is because the patent and innovation data are annual. I restrict the sample period to 1984-2006, since the liquidity creation data goes back to 1984 and patent and citation data end in 2006.

balance sheet activities are also similar to on-balance sheet activities. Positive weights are consistent with the theoretical notion that by creating liquidity banks actually take something illiquid from the public and in turn give the public something liquid. Negative weights are also in line with the theoretical notion that banks can destroy liquidity by financing liquid assets with illiquid liabilities or equity. The construction of the Berger and Bouwman (2009) bank liquidity creation measures is outlined in Appendix A.

In this study, the main independent variable is state-level liquidity creation normalized by the state's total gross assets held by banks (Berger and Bouwman, 2009). I normalize my liquidity creation variables to improve comparability across states and to avoid giving unnecessary weights to the largest states.

I use quarterly data on bank liquidity creation.[6] To match the frequency of the patent and citation data, I calculate all liquidity creation measures at the annual frequency by taking the annual average of each liquidity creation measure for each bank in each year and then I aggregate these data to the state level. In further analyses, I also compute the liquidity created by small and large banks. On-balance sheet liquidity creation (*LC-OnBS*) and off-balance sheet liquidity creation (*LC-OffBS*) are also computed using Berger and Bouwman's (2009) procedure.

Most banks operate in a single state. However, there are some cases where banks also operate in multi-states. In the single-state cases, I simply aggregate the liquidity creation measures for all banks in the state. For banks that operate in multiple states, I assume the liquidity creation is geographically distributed according to the deposits of the bank. For this purpose, I extract the data from The FDIC's Summary of Deposits (SoD) which reports the amount of deposits held by banks

[6] https://sites.google.com/a/tamu.edu/bouwman/data

in each office in the US.[7] As a robustness check, I only include single-state banks to mitigate the attenuation bias generated from the measurement error.

3.3. Control variables

I include different control variables following the innovation literature. To control for the innovation input, I use the logarithm of one plus R&D spending (*LnRD*). To ensure that the results are not driven by the demand channel, I include return on assets (*ROA*) and cash holding (*Cash*) in the baseline regressions. These two variables are also controlled for the role of a firm's reliance on internal resources in financing innovation (Himmelberg and Petersen, 1994).

In addition, firm leverage and capital expenditure are included to control for the role of financial dependencies. I also control for the time-varying state's economic activity. In particular, I include the annual growth rate of gross state product (*GDP*), and I estimate the state economy's comovement with the rest of the US (*Correlation*) using monthly values of coincident indexes from 1984 to 2006.[8] To control for local output, I include the annual growth rate in personal income (*PI*) in the state.

Rice and Strahan (2010) construct an index of interstate branching restrictions. As described in their paper, the Interstate Banking and Branching Efficiency Act (IBBEA) allowed states to employ interstate branching for the first time since 1927, letting banks expand across states. Specifically, states could set regulations on interstate branching based on four provisions as

[7] This assumption is crucial since this is the only balance sheet variable available that determines location.

[8] In an unreported test, I also control for state level political economy variables, governor and legislature dummies. I run all models including governor and legislature dummies, and the results remain unchanged.

follows: the minimum age of the target institution, de novo interstate branching, the acquisition of individual branches, and a statewide deposit cap. The Rice and Strahan Index (*RSI*) adds one to the index when a state adds any of the four restrictions just described. Thus, *RSI* ranges from 0 to 4, with zero indicating that the state is most open to out-of-state entry, and four indicating that the state is most restrictive to out-of-state entry.

Following Rice and Strahan (2010), I control for interstate branching restrictions as a proxy for bank competition and state-level banking environment in the baseline model (Cornaggia et al., 2015). Shenoy and Williams (2017), update *RSI* to 2008. According to their paper, in 2005 Montana permitted interstate de novo branching by out-of-state banks, and in 2006, Mississippi permitted interstate branching through the acquisition of single branches or other portions of an institution and through de novo branching. Therefore, I update the value of RSI for these two states after 2004. In addition, to control for the other dimensions of banking sector development, I include the logarithm of bank assets (*Lnta*) in the regression. Controlling for this dimension is critical because this paper aims to demonstrate the relative importance of bank liquidity creation as a crucial bank activity.

Table 2 provides summary statistics of the variables used in this study. The sample consists of annual state-level observations for 50 states of the US over 1984-2006. On average, banks in a state create 0.411 liquidity per unit of assets. At the firm-state level, firms have *ROA* of 8.2%, leverage of 30.4%, *CAPEX* of 4.6%, cash holding of 5.3%, and the average value of *RSI* is 3.3 in the sample.

[Insert Table 2 here]

4. Methodology and empirical results

4.1. The baseline model

To assess how bank liquidity creation affects technological innovation, I estimate the following model[9]:

$$INNOV_{i,\, t+1\ to\ t+3} = \alpha + \beta LC_{i,t} + \gamma Z_{i,t} + Year_t + State_i + \varepsilon_{i,t} \quad (1)$$

where *i* indexes state and *t* indexes time. The dependent variable is alternatively one of the following: the natural logarithm of one plus the number of patents generated in each state in the subsequent three years (*Lnpat*) or the natural logarithm of one plus the number of citations in the following three years (*Lncite*). LC is alternatively one of the following: state *i* total level of bank liquidity creation (*Total LC*), on-balance sheet liquidity creation (*LC-OnBS*), or off-balance sheet liquidity creation (*LC-OffBS*). Z is a vector of controls that includes *Lnta*, *CAPEX*, *LEV*, *GDP*, *Cash*, *LnRD*, *ROA*, *Correlation*, *RSI*, and *PI*. $Year_t$ and $State_i$ are year fixed-effects and state fixed-effects. Including state fixed-effects controls for unobservable omitted variables from Eq.1 that are constant over time. For example, including state fixed-effects will remove any persistent differences in the structure of the industry or the bargaining power of the banks, because these differences tend to be persistent. Innovation is likely to be autocorrelated over time, therefore I cluster standard errors by states to avoid inflated t-statistics (Petersen, 2009).

Table 3 reports the first set of regression results. Columns 1 and 3 of Table 3 only include state and year fixed-effects as control variables, while columns 2 and 4 show the results for my

[9] The unit of the analysis is based on state-year observations following previous similar studies (see e.g., Chava et al., 2013; Berger and Sedunov, 2017).

full model. As shown in columns 1 to 4, the coefficient estimates on liquidity creation are negative and statistically significant across all model specifications. For example, the coefficient estimates in full models in columns 2 and 4 suggest that a one standard deviation increase in bank liquidity creation is related to an economically significant 1.7% and 1.5% decrease in the quantity and quality of innovation respectively.[10] The result suggests that bank liquidity creation may decrease rather than increase innovation. The result is broadly consistent with the finding of Hombert and Matray (2017), who document that relationship lending reduces the number of innovative firms.

Regarding the control variables, I find that greater innovation input (*LnRD*) is associated with more innovation output. The positive and significant effect of *RSI* on technological innovation is also consistent with the previous finding of Cornaggia et al. (2015), implying the banking competition has a negative impact on innovation. In addition, I find a positive association between the firm's profitability and capital expenditure and its innovation output.

[Insert Table 3 here]

For further analysis, I investigate the effect of on- and off-balance sheet liquidity creation on technological innovation. In particular, I replace total liquidity creation with on- and off-balance sheet liquidity creation. The results are reported in Table 4. Even though on-balance sheet liquidity creation does not explain the cross-sectional variation in technological innovation, the bank's off-balance sheet activities have a negative impact on innovation. Using the coefficient from the models in Table 4, I find that a one standard deviation increase in banks' off-balance sheet liquidity

[10] The economic impact is defined as a standardized coefficient (regression coefficient times its corresponding standard deviation) over the mean of the dependent variable.

creation is associated with an almost 1.8% and 1.5% decrease in patents and citations, respectively. This result shows the important role of banks' off-balance sheet activities. Strahan (2008) also argues that the channel of liquidity creation from lines of credit and loan commitments is more important than the asset side. Because innovation projects are risky, unpredictable, hard to price, and have limited collateral values, banks may accelerate loan terms, or terminate unused lines of credit following covenant violation (see e.g., Gu et al., 2017). Therefore, increased commercial lending through off-balance sheet activities may discourage innovation.

[Insert Table 4 here]

4.2. Asset tangibility

Innovative firms may have few tangible assets, and therefore banks might be less willing to lend against the security of intangible assets. Due to information asymmetry, low redeployability, and higher uncertainty in liquidation value, intangible assets might tend to represent poor collateral, and increase intermediation frictions (see e.g., Williamson, 1988; Shleifer and Vishny, 1992). Asset-backed lending may solve the moral hazard problem in lending, and detect firm insolvency much faster than other types of lending. Therefore, banks might allocate their lending capacity towards those firms with more tangible assets. Collateralizable assets can increase borrowers' and lenders' ability to deal with the agency problem relating to debt financing. For firms with more tangible assets, decreased intermediation frictions may be akin to a positive supply credit shock. A recent study by Dell'Ariccia, Kadyrzhanova, Minoiu, and Ratnovski (2021) documents that a shift from tangible to intangible capital in the past few decades in the US has induced banks to reallocate their balance sheet from financing innovative projects that rely on intangible assets toward well-collateralized investments such as mortgages.

Given that prior literature suggests that asset tangibility may influence a firm's credit constraints, and a decline in innovation is more pronounced for firms with fewer tangible assets (see e.g., Almeida and Campello, 2007; Hombert and Matray, 2017), I next explore whether innovation output by firms with more tangible assets is affected by bank liquidity creation. To answer this question, I aggregate innovation output by firms that have above-median asset tangibility in each state. Asset tangibility is defined as Property, Plant & Equipment divided by the book value of total assets. The results are reported in Table 5. Interestingly, I observe a positive and significant effect of liquidity creation on the quantity of innovation productivity for firms with above-median tangible assets. While being not statistically significant, I observe a qualitatively similar pattern for the quality of the innovation output. These findings suggest that bank liquidity creation enhances innovation by firms that have above-median asset tangibility. Specifically, these regressions suggest that the provision of bank liquidity might move the comparative advantage from innovative sectors to more tangible sectors as the negative linkage between liquidity creation and innovation pertains to firms with lower tangible assets.

Overall, the analysis in Table 5 reveals that bank liquidity creation has a positive effect on innovation output by firms that have above-median tangible assets, while being negatively associated with innovation output by firms that have below-median asset tangibility.

[Insert Table 5 here]

4.3. The role of the bank and firm size

Given that some empirical studies show that bank size influences the level of liquidity creation (see e.g., Kashyap et al., 2002; and Berger and Bouwman, 2009), it is interesting to examine the effect of bank liquidity creation on technological changes by bank size class. For this purpose, I split my sample of banks into two subsamples using a cutoff point of $1 billion in gross total assets following the banking literature. Banks with gross total assets exceeding $1 billion are considered large banks, and banks with gross total assets of up to $1 billion are considered small banks. I re-estimate the baseline model, but I replace the total liquidity creation measures with the two size-based liquidity creation. The results are presented in columns 1 and 2 of Table 6.[11] As can be noted from columns 1 and 2 of Table 6, the coefficient estimates on liquidity creation by large banks are negative and statistically significant at the 1% level. However, the coefficient on liquidity creation by small banks is positive and statistically significant for the patented innovation, while being insignificant for citations. These findings reveal that small banks are more likely to promote firm innovation. The results are broadly consistent with the findings of Berger and Sedunov (2017), who document that small bank liquidity creation is more important to economic growth than large bank liquidity creation.

To further understand these results, I conduct additional tests that explore the role of large and small banks in innovation output for large and small firms. Specifically, I define small and large firms based on the median of the total number of employees as a threshold, and aggregate the innovation output by firm size class. Columns 3 to 6 of Table 6 present the results for this

[11] The number of observations is lower in these model specifications because there are no large banks in some states for some particular years. Therefore, there are missing values for large banks in the sample.

additional analysis. In general, the banking literature suggests that large banks tend to lend to relatively large, and transparent firms using “hard” information technologies such as financial statements, while small banks have advantages to lend to small and opaque firms using “soft” information technologies such as personal knowledge about its owner, and management. Contrary to the prediction of this paradigm, Berger and Black (2011) show that small banks have the strongest comparative advantage for lending to the largest firms. Their results also suggest that the comparative advantages of large banks in lending to different-sized firms are not increasing monotonically. Consistent with this view, the findings suggest that small bank liquidity creation enhances the technological innovation only by large firms. For example, using the coefficient estimates in column 5, a one standard deviation shift in the liquidity created by small banks is associated with a 1.6% increase in the patented innovation over the sample mean. In addition, when focusing on the effect of small and large bank liquidity creation on innovation by small firms, the results in columns 3 and 4 suggest that small and large bank liquidity creation is negatively associated with small firm innovation output. Even though the coefficient estimates of small and large bank liquidity creation are insignificant, the results may suggest that moral hazard and asymmetric information problems are more acute for small firms, and these firms are likely to suffer when financing their risky innovative projects. Overall, the findings in Table 6 show that small bank liquidity creation may be more important in promoting firm innovation. In addition, small banks may have the strongest comparative advantage to enhance large firm innovation.

[Insert Table 6 here]

4.4. Endogeneity concerns

The results from the baseline regression analysis suggest that there is a negative relationship between bank liquidity creation and technological innovation. However, the findings may potentially suffer from endogeneity problems in the sense that banks might grow more in the states with higher technological innovation, or shrink in states with low innovation productivity. To understand how and whether changes in bank liquidity creation have any confounding effect on innovation, I first utilize the policy changes to empirically determine how the deregulation of branching affects banking and nonbanking institutions. Second, I use the instrumental variable approach to further address the potential endogeneity concern for causality referencing.

4.4.1. The difference-in-differences approach

My first empirical strategy is to exploit branching deregulation and analyze how shocks to bank liquidity creation affect firms' innovation output. Relaxing state branching restrictions within state borders can act as shocks to the relationship between bank liquidity creation and innovation. The staggered timing of the intrastate branching deregulation provides an ideal setting to empirically examine whether the findings are explained by state-wide credit supply shocks. The removal of the intrastate branching restrictions began in the 1970s and ended in the late 1990s. This allows me to use states that had not passed the removal of restrictions at a point in time to control for potentially confounding effects. I estimate the differences in innovation by firms in a state before and after the removal of restrictions to such differences for firms in states where intrastate banking deregulation has not passed during the same time period. If relaxation of intrastate restrictions decreases innovation output, I would expect a decrease in innovation after lifting state branching prohibitions. I obtain the timing of the branching deregulation in different states from Jayaratne and Strahan (1996) and create a dummy variable for the intrastate branching deregulation, which equals one for the time after the state removed the branching restrictions and zero otherwise, and perform a generalized difference-in-differences approach. A key advantage of using this natural setting is that state-wide deregulation and changes in bank liquidity creation over time within the same state are uncorrelated with economic activities and characteristics that may be determinants of innovation. I estimate the effect of relaxing credit constraints on innovation as follows:

$$Y_{i,t}=\alpha + \beta Deregulation_{i,t} + \gamma Z_{i,t} + Year_t + State_i + \varepsilon_{i,t} \qquad (2)$$

where i indexes state and t indexes time. The dependent variable ($Y_{i,t}$) is alternatively one of the following: the natural logarithm of one plus the number of patents generated in each state and year or the natural logarithm of one plus the number of citations in each state and year. The key variable of interest is the coefficient of the deregulation which is estimated as the difference between the change in innovation before and after deregulation with the difference in innovation for the control group not experiencing a policy change in their deregulation stands. To empirically examine the effect of a credit supply shock on innovation, I use the 1984-1999 time period to perform the difference-in-differences approach. The definition of other variables is the same as Eq.1.

[Insert Table 7 here]

In addition to E.q.2, I empirically explore whether the policy change has a confounding effect on the number of patents and citations generated in the following one to three years. The results are reported in Table 7. As can be seen from Columns 1-8, the coefficient on branching deregulation is negative and statistically significant, implying that the removal of branching restrictions tends to decrease state-wide innovation output.

4.4.2. The instrumental variable approach

To further mitigate endogeneity concerns, I re-estimate the baseline model using a two-stage least squares (2SLS) instrumental variable approach. Following Berger and Sedunov (2017), I use bank equity per capita as an instrumental variable. I believe that bank capital satisfies the exclusion restriction because it is implausible that bank capital affects innovation outside of liquidity creation. In other words, it is unlikely that bank capital would have a direct impact on firm innovation. However, it may influence innovation through its impact on bank liquidity creation. Specifically, bank equity capital should affect innovation through lending, deposits, and off-balance sheet activities which are all the components of bank liquidity creation.[12]

[Insert Table 8 here]

Table 8 represents the results of the 2SLS model. Column 1 reports the first-stage result, and columns 2 and 3 show the results for the second stage by using the predicted value of bank liquidity creation from the first-step regression. From column 1, I find that bank equity positively predicts

[12] In unreported test, I also perform reverse causality following the methodology of Granger (1969). Specifically, I run regressions of liquidity creation on innovation variables and liquidity creation, using the first lags, and control variables. The results suggest that innovation does not Granger-cause bank liquidity creation.

bank liquidity creation as previously documented by Donaldson, Piacentino, and Thakor (2018). In columns 2 and 3, I find that the coefficient estimates on total LC are still negative and statistically significant. Overall, the main findings are robust to the instrumental variable regression.

4.5. Mechanism

I explore a possible mechanism through which bank liquidity creation may affect innovation output. Specifically, I examine whether the overall relation between bank liquidity creation and innovation is through bank-dependent industries, and how the overall relation between bank liquidity creation and innovation differs depending on the industry-level reliance on external finance. Given that a previous study by Rajan and Zingales (1998) documents that industries that are more dependent on external financing expand faster in developed financial systems, I expect that bank liquidity creation is less likely to influence industries that have better access to capital markets.

To further understand the previously obtained findings, I use industry heterogeneity within states and aggregate the innovation output across firms in the same two-digit NAICS code industry in each state and year. Table 9 only presents the coefficient estimates on liquidity creation using the state-industry-level innovation output as dependent variables. I include but do not report all the controls and state and year fixed-effects from the baseline model in E.q 1.

Lerner, Speen, Baker, and Leamon (2016) document that patented innovations in the finance industry are different and highlight the deficiencies in financial patenting. In addition, prior studies have acknowledged that the reported R&D in the finance industry is relatively low and the productivity gain in this industry is modest compared to other sectors (see e.g., Kung, 2020), which may cast doubt on the social welfare-enhancing effect on innovation in this particular industry. Despite a dramatic surge in information technology and an increase in the overall size of financial intermediation, Philippon (2015) shows that the cost of intermediation has been remarkedly constant for more than a century. Among other papers, a theoretical model of Gennaioli, Shleifer, and Vishny (2012) also shows that financial intermediation meets investors' desire to have securities with safe cash flows by engineering securities perceived to be safe but actually exposed to hidden risks. When these neglected risks become apparent, the allocation of risk and investment is distorted in the economy and the social welfare suffers. Consistent with these views, my findings show that the observed negative association between bank liquidity creation and corporate innovation is mainly driven by the finance industry. In contrast, liquidity creation is positively associated with innovation in industries such as information technology and wholesale trading, which may be consistent with the high growth rate of the business investment in information technology in the 1990s and early 2000s.

[Insert Table 9 here]

4.6. Asymmetric relationship

A natural question that emerges from the observed negative relation between bank liquidity creation and innovation output is whether the linkage between liquidity creation and innovation productivity is asymmetric. To capture the potentially asymmetric effects in liquidity creation, I decompose the total liquidity creation measure into positive and negative components. Especially, I define:

$$LC^{+}_{it} = LC_{it} - LC_{it-1} \ \text{if} \ (LC_{it} - LC_{it-1}) > 0 \text{, otherwise } 0,$$

$$LC^{-}_{it} = LC_{it} - LC_{it-1} \ \text{if} \ (LC_{it} - LC_{it-1}) < 0 \text{, otherwise } 0. \quad (3)$$

where LC_{it} is the change in liquidity creation divided by change in total assets at state i from t to t-1. I then replace the total liquidity creation measure with the positive and negative components in the baseline model. This approach allows me to compare the effect of negative and positive shocks of bank liquidity creation on innovation productivity. Panel A of Table 10 reports these results. The estimates suggest that a positive change in total liquidity creation is negatively associated with innovation output, while a decrease in liquidity creation has a positive but insignificant impact on innovation. This difference is statistically significant suggesting that the effect of bank liquidity creation on innovation output is asymmetric.

[Insert Table 10 here]

Second, I examine how the effect of bank liquidity creation on innovation output changes over business cycle fluctuations. To investigate this question, I identify the expansion and recession periods using the information provided by the Federal Reserve Bank of St. Louis. Using the annual smoothed US recession probabilities obtained from a dynamic-factor Markov-switching model, the Federal Reserve Bank of St. Louis identifies two recession periods from 1984 to 2006.[13]

[13] Chauvet and Piger (2003, 2008) analyze the performance of a parametric Markov-switching dynamic-factor model, and they find that this model accurately identifies the NBER business cycle chronology.

In particular, the first recession occurred in the early 1990s (1990-1991), and the second recession hit the US economy in the early 2000s (2000-2001).

The theoretical model of Aghion and Saint-Paul (1998) suggests that firms behave differently during economic booms and contractions. Firms tend to invest more in productivity-enhancing projects during recessions because the opportunity cost of long-term innovative investments instead of short-term working capital investments is lower during economic contractions than economic booms. Also, the theory of "creative destruction" proposed by Schumpeter suggests that recessions could have a positive impact on aggregate productivity, because economic downturns may shift factors of production from less productive to more productive ones.[14] Hence, I expect that the effect of bank liquidity creation on innovation productivity is different over the business cycle.

Panel B of Table 9 provides insight into the relationship between bank liquidity creation and innovation output during economic contractions and expansions. From Panel B of Table 10, I observe that during economic expansion there is a negative relationship between bank liquidity creation and innovation output. Acharya, Shin, and Yorulmazer, (2009) show that risk-shifting incentive encourages banks to hold risky and illiquid assets during boom periods because risky investments are more likely to pay off well during these periods. Since business cycle fluctuations are related to fluctuations in searching for risky loans by banks, banks' desire for risk increases during economic booms, and thus they may start financing undesirable high-risk projects due to adverse selection. This misallocation of capital may lower productivity, and lead to more default and less growth. This would explain the overall negative relation between liquidity creation and

[14] Schumpeter (1934) notes that "[Recessions] are but temporary. They are the means to reconstruct each time the economic system on a more efficient plan.".

technological innovation during boom periods. In addition, the model of Thakor (2005) shows that during the market boom the supply of credit increases inefficiently which results in over-lending by banks. His findings suggest that during economic booms banks' desire for risks increases, and greater liquidity creation may occur off their balance sheet. Consistent with this, my data indicates that off-balance sheet banking activities are the main driver of the observed negative relationship between bank liquidity creation and innovation during economic expansions.

Overall, the results demonstrate that the effect of bank liquidity creation on innovation output is asymmetric, and these results are consistent with recent empirical work suggesting a complex relationship in the finance-growth nexus.

5. Robustness checks

To ensure the robustness of my analyses, I perform a series of alternative estimations and tests. These tests are reported in Table 11.

First, to ensure that the results are not driven by the denominator of bank liquidity creation measure, I scale bank liquidity creation by bank total deposits instead of bank total assets.[15] The results reported in columns 1 and 2 of Table 11 show that the main findings hold when using the alternative approach for the liquidity creation measure.

Second, to ensure that the results are not driven by the method of allocating bank liquidity creation proportionally according to the deposits held in their different branches in multiple states, I re-estimate the baseline model for only single-state banks. For this purpose, I exclude all banks

[15] The results do not change if the liquidity creation is scaled by state population.

which operate in multiple states from my sample. From columns 3 and 4 of Table 11, I observe that the results do not differ from earlier findings.

Third, to disentangle demand and supply effects, in columns 5 and 6, I use a combination of firm-specific-year and country-year fixed effects. Specifically, I use *State* × *Year* fixed effects to absorb any potentially confounding demand factors. These particular fixed effects control for aggregate demand factors that may impact all firms in a given state at a given time. In addition, *Cash* × *Year* fixed effects and *ROA* × *Year* fixed effects are included in the regression to control for all unabsorbable time-varying factors that may drive the demand for commercial loans. Consistent with the main results, I find a negative and significant effect of bank liquidity creation on innovation output even after controlling for any potentially confounding demand factors.

Next, I explore the effect of bank liquidity creation and innovation over a shorter and longer time period. Specifically, in columns 7 and 8, I re-estimate the baseline model using the natural logarithm of one plus the total number of patents and citations in a state in the following two years.[16] The results show that there is a negative association between bank liquidity creation and corporate innovation when looking at a shorter time horizon. Further, I use cumulative innovation output in the next following four years. In particular, I re-estimate the baseline model using the natural logarithm of one plus the state total number of citations received on the firm's patents filed in years *t+1* through *t+4*, and I find the results continue to hold.

[Insert Table 11 here]

[16] The innovation process generally takes place longer than one year. The average lag between a patent's application year and its grant year is almost two years.

Finally, following Hall et al. (2001), I adjust patent counts, and citations using the "fixed-effect" approach instead of the "quasi-structural" approach, and then re-estimate the baseline model. For this purpose, the citations are adjusted by scaling each citation count by the average number of citations received by all patents granted in the same technology class and year. Similarly, patent counts are adjusted by dividing each patent by the average number of patents of all firms in the same technology class and year. As can be noted from columns 11 and 12 of Table 11, the results also hold when the alternative method is used for correcting the truncation bias in the patent and citation dataset. [17]

6. Conclusion

In this paper, I present the empirical evidence that bank liquidity creation stymies innovation. Given the important role of intangible assets in the knowledge-based economy, the findings in this paper stress the limited role of banks during the transition to a knowledge economy. Further analysis reveals that bank liquidity creation enhances innovation only among those firms with higher tangible assets. The empirical findings also suggest that although bank liquidity creation adversely affects firms' innovation on average, this effect mainly comes from the group of firms with below-median asset tangibility. Taken together, these results indicate that bank liquidity creation might move the comparative advantage from innovative sectors to more tangible sectors.

[17] In addition to all aforementioned robustness checks, in an untabulated report I check whether the results are driven by the vast majority of IPOs and startups in state of California and New York. For this purpose, I remove California and New York from the sample and re-estimate the baseline models, and I find similar results reported in Table 3.

Moreover, I find that small bank liquidity creation may be more relevant for promoting large firm innovation. This result is consistent with the findings of Berger and Black (2011), who document that small banks have the strongest comparative advantage for lending to the largest firms. I also explore the mechanism through which bank liquidity creation may affect innovation, and I find that the observed negative relation between bank liquidity creation and innovation is mainly driven by the finance industry, which is consistent with previous findings showing that financial innovation may have an adverse effect on social welfare. This result suggests that policymakers may need to pay closer attention to the innovation generated by the financial sector as they might behave differently to other sectors and may have adverse consequences on economic growth in the long run.

Given that bank liquidity creation, on average, has a negative impact on innovation, other growth-enhancing strategies may need to be implemented in keeping long-run economic benefits. In addition, knowing the efficient and optimal levels of financial resources for productive activities is crucial to ensure the effectiveness of bank liquidity creation for economic growth.

This paper has several implications for future research. While in this study, I focus on the role of bank liquidity creation in technological innovation, more research is needed on the role of liquidity created, for example, by non-bank financial institutions. Given that prior studies have acknowledged that firms with more intangible assets are more likely to rely on non-bank financial institutions, it is interesting to shed light on the importance of liquidity created by non-bank enterprises in the transition to the knowledge-based economy. In addition, since liquidity creation inherently reduces the liquidity of the bank, and may have negative externalities to the financial system stability, more research is needed to understand how and whether the negative externalities and fragility of banks due to their activity of liquidity creation affects technological innovation.

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Table 1. Variable definitions and sources.

Variables	Definition	Sources
Lnpat	Natural logarithm of one plus the state total number of patents filed by assignees in the state s in years t+1 through t+3. Patent counts are adjusted using the "weight factors" computed from application-grant empirical distribution (quasi-structural approach).	NBER patent database
Lncite	Natural logarithm of one plus the state total number of citations received on the firm's patents filed by assignees in the state s in years t+1 through t+3. I use the variable "hjtwt" provided by the NBER database. It is adjusted using the "weight factor" computed from citation-lag distribution (quasi-structural approach).	NBER patent database
Lnpat-fixed	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+3. Patent counts are adjusted using the "fixed-effect" approach by scaling each patent by the average number of patents of all firms in the same year and technology class (HJT tech category).	NBER patent database
Lncite-fixed	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+3. Citation counts are adjusted using the "fixed-effect" approach by dividing each citation count by the average number of citations received by all patents granted in the same year and technology class (HJT tech category).	NBER patent database
$Lnpat_{t+2}$	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+2. Patent counts are adjusted using the "weight factors" computed from application-grant empirical distribution (quasi-structural approach).	NBER patent database
$Lncite_{t+2}$	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+2. I use the variable "hjtwt" provided by the NBER database. It is adjusted using the "weight factor" computed from citation-lag distribution (quasi-structural approach).	NBER patent database
$Lnpat_{t+4}$	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+4. Patent counts are adjusted using the "weight factors" computed from application-grant empirical distribution (quasi-structural approach).	NBER patent database
$Lncite_{t+4}$	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+4. I use the variable "hjtwt" provided by the NBER database. It is adjusted using the "weight factor" computed from citation-lag distribution (quasi-structural approach).	NBER patent database
Total LC	Total liquidity created by banks in the state, normalized by gross total assets held by banks in the state.	Berger and Bouwman (2009)
LC-OnBS	Total on-balance sheet liquidity created by all banks in the state normalized by gross total assets held by banks in the state.	Berger and Bouwman (2009)
LC-OffBS	Total off-balance sheet liquidity created by all banks in the state normalized by gross total assets held by banks in the state.	Berger and Bouwman (2009)
Small bank LC	Total liquidity creation of banks in the state with less than or equal to $1 billion in gross total assets, normalized by gross total assets held by small banks in the state.	Berger and Bouwman (2009)
Large bank LC	Total liquidity creation of banks in the state with greater than $1 billion in gross total assets, normalized by gross total assets held by large banks in the state.	Berger and Bouwman (2009)
Total LC-single	Total liquidity created by all banks in the state that only operates in that state, normalized by all gross total assets held by banks in the state that only operates in that state	Berger and Bouwman (2009)

Bank equity	Total equity held by banks in the state.	Call Reports
Rice-Strahan Index (RSI)	Rice-Strahan index of interstate banking deregulation. It ranges from 0 (least restrictive) to 4 (most restrictive).	Rice and Strahan (2010)
US/state Correlation	State economy comovement with the rest of the US, measured as the correlation of the state's coincident index which is estimated based on monthly values of the indexes over 1984-2006.	Federal Reserve Bank of Philadelphia
Lnta	Natural logarithm of total assets held by banks in the state.	Call reports
GDP	The nominal gross product in state *i* in year *t*.	US Bureau of Economic Analysis
PI	Annual percentage change in personal income in the state.	US Bureau of Economic Analysis
Cash	Total cash and marketable securities of the firms in the state to total assets of the firms in the state.	Compustat
ROA	Return on assets ratio of all firms in the state. It is defined as operating income before depreciation for all firms in the state divided by total assets of firms in the state.	Compustat
LEV	The total leverage ratio of the firms in the state. It is defined as the book value of debt for all firms in the state divided by all firms' total assets in the state.	Compustat
CAPEX	Total capital expenditure of all firms in the state scaled by all firms' total assets in the state.	Compustat
LnRD	Natural logarithm of one plus research and development expenditure.	Compustat

This table presents definitions and sources of different variables employed in this paper. The sample period is 1984-2006. State-level data are reported on an annual basis. Washington, DC is dropped due to a lack of data availability.

Table 2. Summary statistics.

Variable	N	Mean	Std. Dev.	25th percentile	Median	75th percentile
Lnpat	1,000	5.292	2.760	3.258	5.839	7.464
Lncite	1,000	7.300	3.489	5.373	7.983	9.776
Total LC	1,000	0.411	0.377	0.279	0.360	0.436
LC-OnBS	1,000	0.214	0.069	0.169	0.224	0.261
LC-OffBS	1,000	0.197	0.387	0.073	0.123	0.189
Lnta	1,000	17.978	1.136	17.213	17.952	18.746
Cash	1,000	0.053	0.036	0.031	0.047	0.066
GDP	1,000	5.996	3.428	4.180	5.777	8.074
RSI	1,000	3.309	1.234	3	4	4
PI	1,000	5.992	2.616	4.318	5.919	7.720
CAPEX	1,000	0.046	0.044	0.027	0.040	0.055
lnRD	1,000	5.451	2.841	3.268	5.796	7.744
ROA	1,000	0.082	0.084	0.061	0.086	0.106
LEV	1,000	0.304	0.117	0.235	0.287	0.350
correlation	1,000	0.819	0.421	0.911	0.981	0.994

This table contains descriptive statistics for key variables used in the baseline model. The definitions of the variables are reported in Table 1.

Table 3. The effect of bank liquidity creation on technological innovation.

Variables	(1) Lnpat	(2) Lnpat	(3) Lncite	(4) Lncite
Total LC	-0.240***	-0.241***	-0.340***	-0.288***
	(0.083)	(0.074)	(0.079)	(0.065)
Lnta		0.275		-0.030
		(0.236)		(0.260)
Cash		2.207*		1.556
		(1.155)		(1.233)
GDP		0.008		0.025*
		(0.011)		(0.015)
RSI		0.080*		0.098*
		(0.043)		(0.054)
PI		-0.018		-0.014
		(0.012)		(0.020)
CAPEX		4.138**		5.549**
		(2.043)		(2.217)
lnRD		0.290**		0.299**
		(0.132)		(0.128)
ROA		2.116*		3.540**
		(1.130)		(1.353)
LEV		-0.618		0.151
		(0.559)		(0.585)
Correlation		0.030		-0.003
		(0.056)		(0.089)
Constant	4.779***	-2.120	7.055***	4.822
	(0.139)	(4.059)	(0.226)	(4.483)
Observations	1,000	1,000	1,000	1,000
R-squared	0.223	0.353	0.622	0.659
Number of groups	50	50	50	50
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

This table reports the results for the baseline model. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. All variables are defined in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 4. The effect of on- and off-balance sheet liquidity creation on technological innovation.

Variables	(1) Lnpat	(2) Lncite
LC-OnBS	-0.416	0.197
	(1.048)	(1.159)
LC-OffBS	-0.242***	-0.286***
	(0.073)	(0.074)
Lnta	0.267	-0.008
	(0.229)	(0.260)
Cash	2.171*	1.657
	(1.154)	(1.260)
GDP	0.008	0.024*
	(0.011)	(0.014)
RSI	0.081*	0.093*
	(0.043)	(0.048)
PI	-0.018	-0.014
	(0.012)	(0.020)
CAPEX	4.146**	5.527**
	(2.042)	(2.222)
lnRD	0.289**	0.302**
	(0.131)	(0.128)
ROA	2.121*	3.523**
	(1.131)	(1.362)
LEV	-0.618	0.151
	(0.562)	(0.581)
Correlation	0.027	0.006
	(0.049)	(0.079)
Constant	-1.943	4.330
	(3.934)	(4.490)
Observations	1,000	1,000
R-squared	0.353	0.659
Number of groups	50	50
State FE	Yes	Yes
Year FE	Yes	Yes

This table presents the results after decomposing liquidity creation into its two components: on- and off-balance sheet activities. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. All variables are defined in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 5. The role of asset tangibility.

	Above-Median Asset tangibility		Below-Median Asset Tangibility	
Variables	Lnpat	Lncite	Lnpat	Lncite
Total LC	0.236**	0.434	-0.686***	-0.996***
	(0.105)	(0.263)	(0.228)	(0.330)
Lnta	-0.014	-0.572	0.952**	0.700
	(0.243)	(0.377)	(0.361)	(0.472)
Cash	0.081	-0.646	3.206**	2.826
	(0.894)	(1.090)	(1.563)	(1.992)
GDP	0.019	0.039*	-0.020*	-0.003
	(0.013)	(0.021)	(0.011)	(0.018)
RSI	0.078	0.004	0.029	0.180*
	(0.063)	(0.097)	(0.072)	(0.093)
PI	-0.020	0.005	-0.006	-0.002
	(0.017)	(0.028)	(0.016)	(0.027)
CAPEX	4.058*	5.815**	1.855	3.416
	(2.363)	(2.773)	(1.856)	(2.339)
lnRD	0.230*	0.230*	0.245**	0.232*
	(0.130)	(0.124)	(0.108)	(0.120)
ROA	2.255*	3.853**	0.733	2.217
	(1.232)	(1.527)	(1.064)	(1.366)
LEV	0.057	0.612	-0.937*	-0.078
	(0.504)	(0.813)	(0.523)	(0.609)
Correlation	-0.047	-0.158	0.080	-0.027
	(0.058)	(0.108)	(0.071)	(0.147)
Constant	2.812	14.312**	-14.871**	-9.331
	(4.100)	(6.536)	(6.457)	(8.404)
Observations	1,000	1,000	1,000	1,000
R-squared	0.213	0.615	0.512	0.466
Number of groups	50	50	50	50
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

This table reports the effect of bank liquidity creation on innovation output for firms with above-median (below-median) tangible assets. The dependent variables are innovation output aggregated by firms that have above-median (below-median) asset tangibility in each state Asset tangibility is defined as Property, Plant & Equipment divided by the book value of total assets. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. All variables are defined in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 6. The role of the bank and firm size.

	Full sample		Small firms		Large firms	
Variables	Lnpat	Lncite	Lnpat	Lncite	Lnpat	Lncite
Small bank LC	0.413**	0.331	-0.581	-1.151	0.517**	0.512*
	(0.198)	(0.254)	(0.371)	(0.750)	(0.214)	(0.291)
Large bank LC	-0.229***	-0.267***	-0.230	-0.212	-0.015	0.201
	(0.063)	(0.079)	(0.196)	(0.296)	(0.111)	(0.289)
Lnta	0.288	-0.037	0.517	0.365	0.098	-0.541
	(0.219)	(0.212)	(0.362)	(0.557)	(0.278)	(0.378)
Cash	2.872*	2.077	1.417	0.142	2.153	1.312
	(1.709)	(1.763)	(1.474)	(1.700)	(1.892)	(1.944)
GDP	0.016	0.034**	-0.002	0.025**	0.019	0.047**
	(0.011)	(0.013)	(0.007)	(0.011)	(0.013)	(0.022)
RSI	0.063	0.087*	-0.009	0.135	0.045	0.023
	(0.039)	(0.049)	(0.063)	(0.098)	(0.043)	(0.062)
PI	-0.018	-0.011	-0.032**	-0.042*	-0.009	-0.002
	(0.016)	(0.024)	(0.015)	(0.023)	(0.018)	(0.031)
CAPEX	0.987	-1.671	-1.896	-4.337	1.266	-2.448
	(1.649)	(3.042)	(2.221)	(3.697)	(2.043)	(3.511)
lnRD	0.200*	0.201**	0.070	0.039	0.286***	0.333***
	(0.105)	(0.092)	(0.102)	(0.154)	(0.103)	(0.102)
ROA	4.106*	9.296***	5.395***	12.137***	2.046	5.562**
	(2.082)	(2.596)	(1.896)	(2.461)	(1.758)	(2.155)
LEV	-0.691	0.329	0.399	1.787*	-0.787	0.066
	(0.706)	(0.881)	(0.709)	(1.035)	(0.700)	(0.850)
Correlation	0.057	0.024	0.030	-0.149	0.052	-0.013
	(0.046)	(0.072)	(0.065)	(0.145)	(0.055)	(0.078)
Constant	-2.104	4.956	-7.249	-3.533	0.809	13.353*
	(3.962)	(3.701)	(6.345)	(9.756)	(5.149)	(6.779)
Observations	973	973	973	973	973	973
R-squared	0.363	0.689	0.277	50	0.350	0.613
Number of groups	50	50	50	0.493	50	50
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

This table reports the effect of bank liquidity creation on technological innovation by the bank and firm size. Small banks are banks with less than or equal to $1 billion in gross total assets, while large banks are defined as banks with more than $1 billion in gross total assets. Small firms are identified by using the median of the total number of employees as a threshold. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. All variables are defined in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 7. Difference-in-differences approach.

Variables	(1) Patent$_t$	(2) Citation$_t$	(3) Patent$_{t+1}$	(4) Citation$_{t+1}$	(5) Patent$_{t+2}$	(6) Citation$_{t+2}$	(7) Patent$_{t+3}$	(8) Citation$_{t+3}$
Intrastate	-0.299*	-0.512*	-0.335**	-0.478*	-0.343**	-0.442*	-0.311**	-0.312
	(0.159)	(0.266)	(0.152)	(0.250)	(0.142)	(0.223)	(0.139)	(0.198)
Lnta	-0.232	-0.398*	-0.296*	-0.558*	-0.252	-0.416	-0.092	-0.103
	(0.164)	(0.222)	(0.174)	(0.282)	(0.215)	(0.329)	(0.237)	(0.341)
Cash	2.048***	3.518***	2.059**	3.187**	1.991	2.996*	2.022	2.652*
	(0.759)	(1.245)	(0.883)	(1.226)	(1.215)	(1.598)	(1.234)	(1.537)
GDP	0.006	-0.003	0.008	0.004	0.014	0.022	0.013	0.013
	(0.010)	(0.018)	(0.010)	(0.021)	(0.012)	(0.021)	(0.012)	(0.017)
RSI	0.094**	0.149**	0.115***	0.164**	0.116**	0.153**	0.114**	0.146**
	(0.043)	(0.067)	(0.042)	(0.063)	(0.045)	(0.065)	(0.044)	(0.061)
PI	0.005	0.016	0.004	-0.003	-0.002	-0.015	-0.006	-0.013
	(0.013)	(0.027)	(0.015)	(0.030)	(0.015)	(0.025)	(0.016)	(0.022)
CAPEX	3.565	5.771*	3.967	5.679*	4.116*	5.941**	4.274**	6.134**
	(2.279)	(3.188)	(2.410)	(3.250)	(2.314)	(2.908)	(2.055)	(2.392)
lnRD	0.438***	0.616***	0.346**	0.435*	0.327**	0.373*	0.318**	0.344*
	(0.137)	(0.230)	(0.144)	(0.221)	(0.147)	(0.204)	(0.150)	(0.194)
ROA	1.825	2.934*	1.960	2.854*	2.042	3.082*	2.098*	3.168**
	(1.196)	(1.702)	(1.247)	(1.700)	(1.219)	(1.576)	(1.116)	(1.368)
LEV	-0.015	-0.171	-0.250	-0.544	-0.430	-0.745	-0.556	-0.639
	(0.335)	(0.537)	(0.356)	(0.572)	(0.414)	(0.644)	(0.456)	(0.532)
Correlation	-0.056	0.052	-0.142**	-0.117	-0.136**	-0.152	-0.045	-0.003
	(0.055)	(0.112)	(0.057)	(0.115)	(0.061)	(0.111)	(0.068)	(0.102)
Constant	4.976	8.613**	6.612**	12.725**	6.528*	11.161*	4.070	6.054
	(2.981)	(4.249)	(3.006)	(4.865)	(3.773)	(5.727)	(4.173)	(5.994)
Observations	800	800	800	800	800	800	800	800
R-squared	0.426	0.328	0.399	0.267	0.403	0.275	0.401	0.286
Number of groups	50	50	50	50	50	50	50	50
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the results of the estimation of the difference-in-differences approach. The intrastate branching deregulation is a dummy variable that equals one for the time after the state removed the branching restrictions and zero otherwise. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. All variables are defined in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 8. Instrumental variable approach.

Variable	(1) Total LC	(2) Lnpat	(3) Lncite
Bank Equity	0.380***		
	(0.022)		
Total LC		-0.294***	-0.185*
		(0.082)	(0.100)
Lnta	-0.028	0.298**	-0.073
	(0.049)	(0.129)	(0.167)
Cash	0.119	2.204***	1.562*
	(0.120)	(0.657)	(0.877)
GDP	-0.003	0.008	0.025*
	(0.003)	(0.010)	(0.014)
RSI	0.007	0.081***	0.095***
	(0.004)	(0.020)	(0.032)
PI	0.002	-0.017	-0.015
	(0.006)	(0.017)	(0.026)
CAPEX	0.222	4.116***	5.591***
	(0.148)	(0.900)	(1.475)
lnRD	0.021***	0.289***	0.301***
	(0.007)	(0.048)	(0.068)
ROA	0.118*	2.103***	3.564***
	(0.069)	(0.463)	(0.801)
LEV	0.051	-0.619**	0.152
	(0.063)	(0.266)	(0.421)
Correlation	-0.013	0.031	-0.004
	(0.013)	(0.047)	(0.071)
Constant	0.377	-5.749***	-0.297
	(0.755)	(2.001)	(2.640)
Observations	1,000	1,000	1,000
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
P-value of first stage F-test	0.000		

This table presents the effect of bank liquidity creation on technological innovation in a 2SLS setting. Column 1 reports the first-stage result and columns 2 and 3 show the second-stage results. Bank equity is used as an instrumental variable. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. All variables are defined in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 9. State-industry-level regression results.

Panel A		
The number of citations across all firms in each industry	The coefficient on Total LC	t-stats
Professional and Business Service	0.066	0.33
Information	0.887***	4.09
Art, Entertainment, and Recreation	-0.033	-0.24
Mining	0.007	0.04
Agriculture, Forestry, Fishing, and Hunting	0.122	0.69
Construction	0.282	1.52
Manufacturing	-0.249**	-2.06
Transportation and Warehousing	-0.092	-0.69
Wholesale trade	0.392*	1.87
Retail trade	0.173	0.91
Finance, Insurance, and Real Estate	-0.401*	-1.73
Other Service	0.097	1.01
Education and Health Care	-0.069	-0.52
Panel B		
The number of patents across all firms in each industry	The coefficient on Total LC	t-stats
Professional and Business Service	-0.249**	-2.1
Information	-0.073	-0.61
Art, Entertainment, and Recreation	0.019	0.22
Mining	-0.054	-0.58
Agriculture, Forestry, Fishing, and Hunting	0.027	0.26
Construction	0.054	0.76
Manufacturing	-0.161	-1.49
Transportation and Warehousing	-0.124*	-1.71
Wholesale trade	0.036	0.41
Retail trade	-0.019	-0.21
Finance, Insurance, and Real Estate	-0.419**	-2.43
Other Service	0.029	0.85
Education and Health Care	-0.133	-1.67

This table reports the coefficients and t-statistics for liquidity creation using the state-industry-level innovation output as dependent variables. The state-industry-level innovation output is the aggregated innovation output across firms in the same two-digit NAICS code industry in each state and year. The sample period is 1984-2006. I include but do not report all control variables, state fixed-effects, and year fixed-effects. All t-statistics are estimated as heteroskedasticity-robust standard errors clustered at the state level. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 10. Asymmetries and the business cycle.

Panel A: Effect of Positive and Negative LC Shocks on Innovation output over

	Lnpat	Lncite
LC+	-0.018***	-0.009*
	(0.006)	(0.005)
LC-	0.002	0.003
	(0.003)	(0.003)
Constant	Yes	Yes
Controls	Yes	Yes
Time FE	Yes	Yes
State FE	Yes	Yes

Panel B: Effect of LC on Innovation output over Business Cycle Phases

	Economic Expansions						Economic Contractions					
	Lnpat	Lnpat	Lnpat	Lncite	Lncite	Lncite	Lnpat	Lnpat	Lnpat	Lncite	Lncite	Lncite
Total LC	-0.243***			-0.297***			0.038			-0.067		
	(0.081)			(0.069)			(0.153)			(0.196)		
LC-OnBS		0.155			0.666			-1.521			0.255	
		(1.049)			(1.100)			(1.705)			(1.953)	
LC-OffBS			-0.239***			-0.306***			0.093			-0.074
			(0.079)			(0.075)			(0.156)			(0.213)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the effect of positive and negative LC shocks on technological innovation, and the effect of liquidity creation on corporate innovation over the business cycle phases. Panel A reports the results after decomposing the total liquidity creation measure into positive and negative components. Panel B reports the results for the effect of liquidity creation on innovation over the business cycle. Economic contractions and expansions are identified using the information provided by the Federal Reserve Bank of St. Louis. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 11. Robustness checks.

Variables	(1) Lnpat	(2) Lncite	(3) Lnpat	(4) Lncite	(5) Lnpat	(6) Lncite	(7) $Lnpat_{t+2}$	(8) $Lncite_{t+2}$	(9) $Lnpat_{t+4}$	(10) $Lncite_{t+4}$	(11) Lnpat-fixed	(12) Lncite-fixed
Total LC					-0.239***	-0.366***	-0.253**	-0.168**	-0.178***	-0.300***	-0.178***	-0.185***
					(0.078)	(0.081)	(0.107)	(0.080)	(0.054)	(0.063)	(0.054)	(0.054)
LC-deposit	-0.104***	-0.136***										
	(0.027)	(0.025)										
Total LC-single			-0.212***	-0.252***								
			(0.075)	(0.067)								
Lnta	0.279	-0.014	0.274	-0.032	0.245	-0.331	0.221	-0.676**	0.224	0.140	0.071	-0.113
	(0.238)	(0.258)	(0.240)	(0.267)	(0.200)	(0.249)	(0.217)	(0.291)	(0.237)	(0.279)	(0.220)	(0.207)
Cash	2.212*	1.561	2.212*	1.562	-1.555	-7.515	2.257*	1.247	2.138*	1.584	1.748*	1.863*
	(1.157)	(1.234)	(1.155)	(1.234)	(3.810)	(6.332)	(1.139)	(1.259)	(1.134)	(1.280)	(1.027)	(1.019)
GDP	0.009	0.025*	0.009	0.025*	0.013	0.014	0.007	0.041**	0.007	0.016	0.016	0.015
	(0.011)	(0.015)	(0.011)	(0.015)	(0.013)	(0.017)	(0.010)	(0.020)	(0.012)	(0.013)	(0.011)	(0.011)
RSI	0.077*	0.097*	0.081*	0.100*	0.062	0.117*	0.068*	0.071	0.063	0.105**	0.077*	0.073
	(0.044)	(0.054)	(0.043)	(0.054)	(0.044)	(0.059)	(0.040)	(0.065)	(0.042)	(0.050)	(0.043)	(0.044)
PI	-0.018	-0.015	-0.018	-0.014	-0.023*	0.005	-0.008	-0.033	-0.017	-0.023	-0.009	-0.003
	(0.012)	(0.020)	(0.012)	(0.020)	(0.012)	(0.020)	(0.013)	(0.024)	(0.013)	(0.019)	(0.012)	(0.014)
CAPEX	4.158**	5.564**	4.138**	5.549**	0.859	0.416	4.090*	5.464*	4.122**	5.862**	3.825*	4.847***
	(2.042)	(2.216)	(2.036)	(2.211)	(1.807)	(3.271)	(2.199)	(2.785)	(1.988)	(2.484)	(2.013)	(1.806)
lnRD	0.291**	0.300**	0.292**	0.301**	0.316**	0.320**	0.325**	0.307**	0.298**	0.275**	0.283**	0.291***
	(0.132)	(0.128)	(0.131)	(0.128)	(0.127)	(0.129)	(0.123)	(0.131)	(0.132)	(0.136)	(0.115)	(0.102)
ROA	2.122*	3.542**	2.118*	3.542**	1.543	5.501	2.113*	3.732**	2.091*	3.449**	2.130*	2.695**
	(1.129)	(1.353)	(1.124)	(1.348)	(2.197)	(3.779)	(1.165)	(1.566)	(1.122)	(1.457)	(1.121)	(1.012)
LEV	-0.600	0.174	-0.616	0.153	-0.697	0.103	-0.492	0.451	-0.696	-0.077	-0.337	-0.118
	(0.558)	(0.583)	(0.558)	(0.585)	(0.692)	(0.888)	(0.500)	(0.687)	(0.599)	(0.586)	(0.492)	(0.391)
Correlation	0.030	-0.003	0.030	-0.003	0.018	-0.007	-0.065	-0.109	0.026	0.006	-0.010	-0.022
	(0.056)	(0.089)	(0.056)	(0.089)	(0.050)	(0.082)	(0.052)	(0.093)	(0.060)	(0.095)	(0.055)	(0.058)
Constant	-2.210	4.506	-2.124	4.820	-1.374	9.431**	-1.666	15.875***	-0.813	2.643	1.370	4.298

	(4.107)	(4.438)	(4.138)	(4.600)	(3.471)	(4.167)	(3.664)	(4.999)	(4.215)	(4.990)	(3.846)	(3.495)
Observations	1,000	1,000	1,000	1,000	1,000	1,000	1,050	1,050	950	950	1,000	1,000
R-squared	0.353	0.659	0.352	0.659	0.381	0.651	0.351	0.701	0.364	0.605	0.495	0.489
Number of groups	50	50	50	50	50	50	50	50	50	50	50	50
State FE	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
State × Year FE					Yes	Yes						
Cash × Year FE					Yes	Yes						
ROA × Year FE					Yes	Yes						

This table reports the results for the robustness checks. All variables are defined in Table 1. The sample period is 1984-2006. Standard errors are estimated as heteroskedasticity-robust standard errors clustered at the state level, and are reported in parentheses. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Appendix A. Construction of liquidity creation measure

Category measure		
Assets		
Illiquid assets (+1/2)	Semiliquid assets (0)	Liquid assets (-1/2)
Commercial real estate loans	Residential real estate loans	Cash and due from other institutions
Loans to finance agricultural production	Consumer loans	All securities (regardless of maturity)
Commercial and industrial loans	Loans to depository institutions	Trading assets
Other loans and lease financing receivables	Loans to state and local governments	Federal fund sold
Other real estate owned	Loans to foreign governments	
Customers' liability on bankers' acceptances		
Investment in unconsolidated subsidiaries		
Intangible assets		
Premises		
Other assets		
Liabilities and equity		
Liquid liabilities (+1/2)	Semiliquid liabilities (0)	Illiquid liabilities and equity (-1/2)
Transaction deposits	Time deposits	Bank's liabilities on banker's acceptances
Saving deposits	Other borrowed money	Subordinated debt
Overnight federal funds purchased		Other liabilities
Trading liabilities		Equity
Off-balance sheet guarantees		
Illiquid guarantees (+1/2)	Semiliquid guarantees (0)	Liquid guarantees (-1/2)
Unused commitments	Net credit derivatives	Net participations acquired
Net standby letters of credit	Net securities lent	
Commercial and similar letters of credit		
All other off-balance sheet liabilities		
Off-balance sheet derivatives		
		Liquid derivatives (-1/2)
		Interest rate derivatives
		Foreign exchange derivatives
		Equity and commodity derivatives

Bank Supervision and Liquidity Creation☆

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Abstract

This paper examines whether different supervisory practices affect banks' liquidity creation. Using a sample of commercial banks in the 27 European countries over 1996-2013, we document a negative association between regulators' supervisory power and bank liquidity creation. However, the level of liquidity creation is unaffected by market-based monitoring. Further analysis reveals that the quality of the institutional environment and market incentives play a crucial role in explaining the cross-country variation in bank liquidity creation. The results of additional analyses suggest that supervisory power and private monitoring affect bank liquidity creation by mitigating liquidity risk, and these two supervisory practices are complementary mechanisms in reducing bank illiquidity. Overall, the results provide new insights into the design of regulatory and supervisory practices of financial institutions.

JEL classification: G20, G21, G28
Keywords: liquidity; governance; bank regulation; supervision

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1. Introduction

Financial regulation and supervision schemes have been a highly controversial issue among policymakers and scholars in the past few decades. Despite the growing literature on the role of bank regulatory and supervisory frameworks for bank stability (see e.g., Barth et al., 2004; Barth et al., 2006; Beck et al., 2006; Chortareas et al., 2012; Barth et al., 2013; Chen et al., 2020), our understanding of how bank regulation and supervision affect banks' ability to create liquidity is very scant. The existing literature on the relationship between bank liquidity creation and bank regulatory and supervisory policies is rather limited to bank regulatory capital (see e.g., Berger and Bouwman, 2009; Distinguin et al., 2013; Fungáčová et al., 2017). What are the real consequences of empowering official supervisory authorities, and private sector monitoring to financial regulators? Despite the importance, this question is understudied in the literature. The purpose of this paper is to examine how these two supervisory policies affect bank liquidity creation.

In general, there are conflicting and inconclusive views on the impact of official supervisory power and private monitoring from an empirical perspective. On the one hand, prior studies have acknowledged that strengthening official supervisory power enhances bank competition, corruption, and loan spreads (see e.g., Beck et al., 2006; Li, 2019; He et al., 2021), but it is not related to bank development, efficiency, and performance (see e.g., Barth et al., 2004; and Barth et al., 2013). On the other hand, the empirical findings of Chortareas et al. (2012) and Hoque et al. (2015) suggest that greater supervisory power is associated with higher bank efficiency and bank-level risk.

Considering the impact of private sector monitoring, previous studies show that market-based monitoring of banks in terms of fostering information disclosure is positively linked to bank development, performance, and efficiency (see e.g., Barth et al., 2004; Barth et al., 2013). In contrast, empirical evidence also shows that greater private sector monitoring can result in higher bank inefficiency, lower risk, and less intensive competition (Chortareas et al., 2012; Hoque et al., 2015; Li, 2019). Given that there are two views that provide contrasting predictions, as discussed by Barth et al. (2006, 2004), the predictions about the effect of these two supervisory practices on bank liquidity creation are not clear ex-ante.[1] Due to these opposing views on supervisory power and market-based monitoring, it is of interest to examine the linkage between bank supervision and regulation and liquidity creation empirically.

Our analysis is motivated by previous theoretical and empirical work. From a theoretical perspective, Mailath and Mester (1994) show that the regulator's policy influences the risk-taking behavior of banks. In the absence of effective and sound supervision, the likelihood of bank distress and bank runs increases when illiquid assets are financed with liquid liabilities (see e.g., Diamond and Dybvig, 1983; Allen and Gale, 2004). From an empirical perspective, a recent study by Berger et. al (2016) finds that regulatory interventions reduce bank liquidity creation using a supervisory German dataset.[2] Using a sample of commercial banks in the 27 European countries, we advance this line of inquiry by focusing on the role of two supervisory systems (i.e. official

[1] More discussion can be found in the relevant literature review and the hypothesis development in Section 2.
[2] Berger et al. (2016) focuses on all the actions taken by authorities in Germany which are more related to restrictions on banking activities and disciplinary actions such as restrictions and prohibitions of lending, deposit taking activities, and profit distributions, instructions to the bank's management, limitations on the scope of managerial decisions, appointment of a trustee, hearing about dismissal of executives, actual dismissal of executives, official disapprovals, fines for the institutions and executives, warnings of executives and threats of measures according to the Banking Act. It does not consider the dynamics between bank supervision, private monitoring, quality of cross-country governance and the ability of banks to create liquidity.

supervisory power and private sector monitoring) in enhancing or impeding the ability of banks to create liquidity.

An answer to the question raised in this paper is an important aspect of a well-functioning financial system and helps policymakers not only to understand the determinants of bank liquidity creation, but also to make informed decisions about the regulation and supervision of the banking system. In this study, bank supervision, and private monitoring are quantified based on surveys conducted by Barth et al. (2004, 2006, 2008, 2013) under the auspices of the World Bank. Overall, the four surveys provide a detailed and comprehensive picture of differences in bank regulation and supervision across various countries. Therefore, the data provide an excellent opportunity to examine the impact of a bank's supervisory environment on bank liquidity creation.

Banks traditionally provide liquidity by funding long-term illiquid assets with short-term liquid liabilities. However, the process of liquidity creation reduces the liquidity of banks and exposes them to different types of risks, such as liquidity risks, and bank runs (Diamond and Dybvig, 1983; Kashyap et al., 2002; Allen and Gale, 2004). [3] In this paper, to measure liquidity provision by banks, we use the three-step procedure of Berger and Bouwman (2009). Each component of liquidity creation such as bank loans and transaction deposits has different theoretically-driven weights based on ease, cost, and time for customers to obtain liquid funds from the bank.

Using data on 220 publicly traded commercial banks in Europe over the period 1996-2013, we obtain the following results. First, a traditional approach to bank supervision that entails strengthening official supervisory authorities tends to decrease bank liquidity creation. This

[3] In the aftermath of global financial crisis, the Basel Committee on Banking Supervision documented "that many banks had failed to take account of a number of basic principles of liquidity risk management when liquidity was plentiful" (Bank for International Settlements, 2008).

finding is consistent with the “supervisory power view”, suggesting that powerful supervisors help prevent banks from engraining in taking excessive risks. The result is also broadly consistent with the finding of Agoraki et al. (2011), who document that official supervisory authorities reduce bank risk-taking behavior. In addition, a supervisory strategy that empowers private monitoring of banks by disclosing accurate information to the private sector does not tend to be related to bank liquidity creation.

To identify the underlying economic channel, we first investigate how bank liquidity creation is affected by a transmission channel that relates higher bank capital to liquidity creation. We find that higher capital has a greater effect in reducing bank liquidity creation in countries where supervisors are incentivized to take timely corrective actions. Second, we investigate how the impact of official supervisory power and private sector monitoring varies across the institutional quality characteristics of individual countries. We find that the observed negative impact of regulators’ supervisory power on liquidity creation weakens at higher levels of the quality of country-level governance. The empirical results also suggest that the effect of private sector monitoring on liquidity creation strengthens at higher levels of the quality of nation-wide governance. Overall, the analysis shows that the empirical findings depend on the type of institutional quality environments. As such, it is important to identify differences in the stringency of law enforcement and institutional quality attributes that can enhance or impede regulatory and supervisory implementation capacity. We then provide further evidence that the effect of private sector monitoring on liquidity creation is more pronounced when there are weaker incentives for the private sector to monitor banks.

The analysis is ended by examining the direct impact of regulators’ supervisory power, and private monitoring, on bank liquidity risk management, as measured by the inverse of the net stable funding ratio, and liquidity transformation gap ratio. We find that the traditional approach to bank supervision that empowers official supervisory authorities tends to decrease bank liquidity risk. Moreover, a supervisory strategy that strengthens private monitoring of banks lowers bank illiquidity. Overall, we find that banks operating in environments with more stringent private sector monitoring and supervisory measures are less exposed to liquidity risk.

In addition to exploring the direct impact of the effectiveness of the two supervisory practices on liquidity risk, we attempt to provide an assessment of the impact that interplay between supervisory power and private monitoring has upon bank liquidity requirements. In particular, we investigate whether and to what extent the effectiveness of the combined effect of supervisory power and private monitoring has a bearing on bank illiquidity. The results suggest that there is an amplifying combined impact of the two supervisory practices on bank illiquidity. Collectively, the empirical findings indicate that policymakers and authorities may need to pay closer attention to the interplay effect of different bank regulatory and supervisory policies, rather than attempting to identify the separate impacts of regulatory and supervisory practices.

This paper contributes to the literature in many ways. First, this paper examines first and foremost whether regulators' supervisory power and private sector monitoring affect bank liquidity creation. In this regard, this study contributes to the recent bank liquidity creation literature. Specifically, we complement and extend the recent findings of Berger et al. (2016) by focusing on the role of the traditional approach to bank supervision, which entails strengthening official supervisory authorities, and a supervisory strategy that empowers private monitoring of banks. Broadly consistent with the negative relation between regulatory interventions and bank liquidity creation documented by Berger et al. (2016), the findings in this paper indicate that banks operating in environments with stringent supervisory practices create lower levels of bank liquidity. Second, we show that the quality of the institutional environment plays a crucial role in explaining the cross-country variation in bank liquidity creation. Therefore, this study enriches our understanding of the role of different institutional quality characteristics on the linkage between supervisory enforcement and the ability of banks to create liquidity. This paper also provides an insight into the design of bank supervision schemes with different implementations capacity in terms of the institutional quality environment. Third, we show that market incentives have an important role in monitoring banks. Disclosing information about banks does not necessarily imply greater private sector monitoring unless market participants have incentives to use the published information to monitor banks. The prevalence of deposit insurance and government interventions in the banking sector may undermine the incentives of market participants to monitor banks. Taken together, a lack of incentives of market participants may diminish the beneficial effect of supervisory monitoring. Thus, bank supervisors and policymakers may need to further improve private incentives to monitor banks. Finally, by examining the conditioning effects of institutional quality and market incentives, we contribute to the wider banking literature that investigates such effects on the association between bank regulatory and supervisory policies and bank stability (see e.g., Chortareas et al, 2012; Cihak et al, 2013; Bermpei et al., 2018).

The rest of the paper is organized as follows. Section 2 presents the relevant literature discussion and hypothesis development. Section 3 discusses the data, measures of bank liquidity creation, and bank supervision. Section 4 presents the methodology and the empirical results. Section 5 provides additional analysis, and Section 6 concludes the paper.

2. Related literature and the hypothesis development

Relatively little is known on the relationship between supervisory power and market-based monitoring and bank liquidity creation. The theoretical study by Mailath and Mester (1994) shows that the regulator's policy influences the risk-taking behavior of banks. Nevertheless, the existing empirical studies are inconclusive and provide conflicting views on the role of official supervisory power on banking system stability. On the one hand, an empirical study by Agoraki et al. (2011) finds that official supervisory power reduces bank risk-taking behavior. Using a dummy variable for one or more interventions by regulators in Germany, such as activity restrictions, pay fines, dismissal of executives, and change process, Berger et al. (2016) recently found that regulatory interventions reduce bank liquidity creation. Empirical evidence by Chortareas et al. (2012) also suggests that official supervisory power can improve bank efficiency. On the other hand, Fernández and González (2005) document that official supervisory power exerts a particularly beneficial effect on reducing bank risk-taking only when auditing and accounting requirements are not implemented. Hoque et al. (2015) also show that empowering official supervisory agencies leads to higher systematic risk and bank risk-taking. Previous studies by Barth et al. (2004, 2013) document that there is no strong association between supervisory power and bank performance, stability, and efficiency.

As discussed in Barth et al. (2004, 2006), according to the "supervisory power view", powerful supervisory authorities can act in the best interests of society and maximize society's welfare. In such a situation, they directly discipline and monitor non-compliant banks and can reduce market failure and overcome market imperfections. Thus, a supervisor with ample powers can help prevent banks from engraining in excessive risk-taking behavior, and thereby bank liquidity creation may decline as well, leading to a reduction in bank illiquidity, and their exposure to liquidity risk. In this regard, we conjecture a negative association between supervisory power and bank liquidity creation. In contrast, according to the "regulatory capture view", powerful supervisory authorities may abuse their power and exert their own private benefits rather than social welfare maximization (Shleifer and Vishny, 1998; Djankov, et. al., 2002; Barth et al., 2004; Barth et al., 2006). Beck et al. (2006) find that official supervisors with ample powers may reduce bank lending integrity which may have an adverse impact on the efficiency of credit allocation. In such a situation, powerful supervisory authorities may force banks to allocate credits to exert political or private benefits. Hence, official supervisory power may have a positive effect on bank liquidity creation.

Apart from the traditional approach to bank supervision, shareholders and other creditors can also monitor and discipline banks through investors' monitoring ability. However, no consensus exists on whether official supervision has an advantage over the private sector in monitoring banks. According to the "private empowerment view", supervisory authorities may not have an incentive to ease market failure because regulators and supervisors do not have an ownership stake in the banks, and thereby, they have different incentives than private creditors for monitoring and disciplining banks. Therefore, facilitating and encouraging private monitoring and market discipline may promote a better functioning banking system. Previous studies have acknowledged that private monitoring of banks can increase bank performance, development, and banks' soundness by reducing moral hazard, which is made by information asymmetries (see e.g., Barth et al., 2004; Fernández and González, 2005; and Hoque et al., 2015). These studies suggest that countries benefit from facilitating private monitoring rather than empowering official authorities. Given that the private sector monitoring can promote better functioning banking systems by lowering banks' riskiness and increasing banks' soundness, we expect a negative association between private monitoring and bank liquidity creation. However, private monitoring might be difficult in a complex and opaque banking sector. For example, Chortareas et al. (2012) find that private sector monitoring can lead to higher bank inefficiency. From this perspective, we expect that private monitoring has a positive impact on bank liquidity creation.

3. Data

The data used in this study are obtained from several sources. To measure bank supervisory power and private sector monitoring, we use the Private Monitoring Index (*PMI*), and the Official Supervisory Power Index (*OSPI*) from the World Bank's Bank Regulation and Supervision Survey, which was conducted in 1999, 2003, 2007, and 2011. Since these surveys are available at only four points in time, we use the previously available survey data until the new one becomes available. In particular, we use the survey data of 1999 during the period 1996-2002, the survey data of 2003 for the years 2003-2006, survey data of 2007 for the years 2007-2010, and survey data of 2011 for years 2011-2013.

The data on the balance sheet of banks are obtained from the Bloomberg database. This database provides a standardized and detailed balance sheet and income statement data. The standardized datasets ensure the accurate representativeness of the banks' sample in each country and extensively and frequently report the detailed balance sheet information for listed banks. Due to unavailable information on private or unlisted banks, we only include listed banks in this study. To compute the liquidity creation measures, we only include banks for which the breakdown of loans based on loan category and the breakdown of deposits based on their maturity are available in Bloomberg. From 1996 to 2013, we identify 220 listed commercial banks in 27 European countries. Table 1 reports the distribution of banks by country.

[Insert Table 1 here]

In addition to the datasets mentioned above, we rely on other data sources in this study. In particular, we use the World Development Indicator (*WDI*) database to obtain economic development variables. To obtain the cross-country private credit, we use the Financial Structure Dataset (Beck et al., 2010). In addition, to compute bank-specific variables, we collect all necessary data on either balance sheets or income statements from the Bloomberg database. Table 2 provides a brief description of all the variables and data sources used in this study. Our final sample consists of more than 2,500 bank-year observations.

[Insert Table 2 here]

3.1. Bank liquidity creation

In this study, we use Berger and Bouwman's (2009) measure of bank liquidity creation. We only measure on-balance sheet liquidity created by banks or their exposure to liquidity risk because there is no detailed breakdown of off-balance sheet data for publicly listed European banks in Bloomberg. Specifically, we use the measure of liquidity creation which incorporates all bank on-balance sheet information.

To compute the liquidity creation measure, all assets, liabilities, and equity are classified as liquid, illiquid, and semiliquid following Berger and Bouwman (2009). In the second step, different theoretically-driven weights are assigned to each item. To summarize briefly, positive weights are given to illiquid assets, and liquid liabilities and negative weights are given to liquid assets, illiquid liabilities, and equity. Positive weights are consistent with the theoretical notion that by creating liquidity banks actually take something illiquid from the public and in turn give the public something liquid. Negative weights are also in line with the theoretical notion that banks can destroy liquidity by financing liquid assets with illiquid liabilities or equity. In the third step, the weighted sum of all on-balance sheet items is calculated. Table 3 shows the balance sheet items and the corresponding weights for calculating bank liquidity creation based on Distinguin et al. (2013).[4] Following Berger and Bouwman (2009), the measure of liquidity creation is normalized by total assets to improve comparability to avoid giving unnecessary weights to the largest banks.

[Insert Table 3 here]

All else being equal, banks can destroy liquidity by financing liquid assets with illiquid liabilities or equity, and banks can create liquidity on their balance sheets by financing relatively illiquid assets such as long-term loans with relatively liquid liabilities such as demand deposits (Bryant, 1980; and Diamond and Dybvig, 1983). Therefore, higher values of liquidity creation show higher bank illiquidity, because banks get more exposed to maturity transformation risk.

[4] Distinguin et al. (2013) also use the on-balance sheet information in Bloomberg to compute bank liquidity creation.

3.2. Bank regulation and supervision

We consider the following two bank regulation and supervision variables in this study. First, we use the Official Supervisory Power Index (*OSPI*) which is a measure of the strength of bank supervision, indicating whether the supervisory authorities have the authority to take specific actions to overcome market failures and prevent and correct problems. This index ranges from 0 to 14, with a higher value indicating the higher power of supervisory authorities. Second, we use the Private Monitoring Index (*PMI*) to measure the degree to which regulatory and supervisory practices require accurate and reliable information disclosure. *PMI* focuses on strengthening the incentive and ability of private investors to exert effective monitoring and governance over banks and it ranges from 0 to 12, with higher values indicating greater private monitoring.

3.5. Control variables

We include three key bank-specific variables: bank riskiness, measured by the ratio of loan loss provisions to total loans (*LLP_TL*); size, measured as a natural logarithm of bank's total assets (*LnTA*); and bank profitability, measured by the ratio of net income to total equity (*ROE*).

Bank market power influences the availability of funds in the banks and it also affects the distribution of the bank's loan portfolios (see e.g., Petersen and Rajan, 1995; Berger et al., 2005). Hence, banks with ample market power are able to increase their transformation activities by attracting more funds and making more loans. Therefore, we include a control for bank *Market Power* measured by the ratio of total assets of bank *i* in country *j* to the total assets of the banking sector in that country.

We also control for various macroeconomic variables. First, we control for the macroeconomic environment by including the natural logarithm of GDP (*LnGDP*) to measure the country's economic development. Second, the ratio of imports plus exports of goods and services to GDP (Karolyi et al., 2012) is included in the regression to control for *Global Integration*. Third, the ratio of private credit to GDP is included in the regression to control for *Banking Development* (Beck et al., 2010).

Table 4 reports the summary statistics of all variables used in this study. As can be noted from the table, the mean value of supervisory power and private monitoring is 9.89 and 7.79 respectively, suggesting heterogeneity in regulators' supervisory power and market-based monitoring across countries. In addition, bank liquidity creation ranges from a minimum of -0.401 to a maximum of 0.841 with a mean value of 0.192. Overall, the table shows significant heterogeneity in terms of liquidity creation, supervisory policies, bank-level characteristics, and macroeconomic data.

[Insert Table 4 here]

4. Empirical results

4.1. Main results

To assess the relationship between bank supervision policies and bank liquidity creation, we estimate the following baseline regression:

$$LC_{ijt}=\alpha+\beta_1 RSP_{jt}+\beta_2 Bank\ Controls_{ijt}+\beta_3 Macro\text{-}Economic\ Variables_{jt}+\theta_j+\gamma_t+\varepsilon_{ijt} \quad (1)$$

where i refers to bank i, j indexes country j, t denotes period. The dependent variable is bank liquidity creation scaled by total assets at bank i in country j in year t (*LC*). RSP_{jt} is one of the following: official supervisory power (*OSPI*), or private monitoring (*PMI*). Bank-level control variables are bank profitability (*ROE*), bank size (*LnTA*), *Market Power*, and riskiness of bank assets (*LLP_TL*). Macroeconomic variables include the country's economic development (*LnGDP*), *Global Integration*, and *Banking Development*. θ_j is country fixed effects and γ_t is the time fixed effects to control for time-invariant country characteristics and business cycles.[5]

[Insert Table 5 here]

Columns 1 and 3 of Table 5 include regulators' supervisory power or private sector monitoring while only controlling for both observed and unobserved heterogeneity across countries. The results indicate that supervisory power is negatively associated with bank liquidity creation, while liquidity creation is mainly unaffected by market-based monitoring. Columns 2 and 4 of Table 5 report the results of the baseline regression. The coefficient estimate of supervisory power is negative and statistically significant, suggesting that strengthening supervisory power is negatively associated with bank liquidity creation. For example, the coefficient estimate in column 2 implies that a one standard deviation (2.31) increase in supervisory power reduces bank liquidity creation by 1.62% (= 0.007 × 2.31). Given that the mean

[5] In untabulated analyses, we apply a dynamic two-step system GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998) for our basiline model to address the potential endogenity problem, and the results remain the same.

value of liquidity creation in dollars is $25.4 billion in our sample, this would translate into a $411.5 million decrease in liquidity creation. This result is broadly consistent with the finding of Agoraki et al. (2011), documenting that official supervisory authorities reduce bank risk-taking behavior. Intriguingly, we find that private sector monitoring is not associated with bank liquidity creation.

As for the control variables, we find that the loan loss provision to total assets (*LLP_TA*) and the return on equity (*ROE*) exert significant effects on liquidity creation, which are negative and positive respectively. These results are consistent with the literature on bank stability (see e.g., Bermpei et al., 2018). We also find that *Global Integration* has a positive and significant association with liquidity creation. This finding is in line with Baradwaj et al. (2016), who find that liberalization of capital control is positively associated with liquidity creation due to the increased mobility of capital flows as a result of financial integration.

4.2. The role of capital structure as a transmission mechanism

Previous studies show that bank capital and liquidity creation are interconnected. Specifically, Berger and Bouwman (2009) discuss two hypotheses on the role of capital on bank liquidity creation: the "*financial fragility-crowding out hypothesis*", and the "*risk absorption hypothesis*". The former predicts that higher capital hampers bank liquidity creation. On the contrary, the latter posits that higher capital enhances liquidity creation. As bank failures can be extremely costly due to the pivotal role that banks play in channeling funds to the economy, supervisors are highly motivated to monitor bank fragility in the system and take preventive and corrective actions if needed. Therefore, to understand how the linkage between supervisory frameworks and liquidity creation is conditional on the bank capital ratios, we examine the interplay effect of higher bank capital on the relationship between supervisory practices and liquidity creation. For this purpose, to capture high bank capital, we create a dummy variable that corresponds to the upper tail of the distribution of the bank capital ratios. In particular, the dummy variable is equal to one if bank capital is above the 90^{th} percentile, and zero otherwise. We then run the regression specified in Eq.1 and include policy variables and their interaction with high bank capital. The results are reported in Table 6.

[Insert Table 6 here]

As can be seen from the table, the interaction term between supervisory power and higher bank capital is negative and statistically significant which is consistent with the conjecture that higher capital has a greater effect in reducing bank liquidity creation in countries where supervisors are incentivized to take timely corrective actions. In terms of the economic significance, a one standard deviation increase in supervisory power increases the impact of capital on bank liquidity creation by 3.70%. This result is consistent with previous studies finding that high capital may stymies liquidity creation by "crowding out" deposits or making banks less fragile (Dimond and Rajan, 2000; Dimond and Rajan, 2001; Gorton and Winton, 2017). Nonetheless, we do not find conclusive evidence for the joint effect of the private monitoring and bank capital.

The estimates confirm that liquidity creation is not only affected by supervisory practices, but also by the transmission mechanism that relates bank capital to liquidity creation. Overall, the results suggest that higher bank capital reduce bank liquidity creation in countries with greater supervision and oversight where the regulators have the incentive and the power to take corrective actions.

5. Other additional analysis

5.1. The role of bank size

The size of financial institutions can determine the suitable regulation and supervision by both official supervisory authorities and the private sector. Given that bank size influences the level of liquidity creation (Berger and Bouwman, 2009), as well as monitoring stringency, bank business models, the regulatory and supervisory practices, it is of interest to investigate the effect of strengthening supervisory power and private sector monitoring on bank liquidity creation by bank size class.

[Insert Table 7 here]

Table 7 shows the results for the impact of bank size on the relationship between regulatory and supervisory policies and bank liquidity creation. Using a cutoff point of $1 billion in total assets, large and small banks are identified. Specifically, banks with total assets exceeding $1 billion are considered as large banks, and banks with total assets of up to $1 billion are considered small banks. The results in Table 7 show that powerful official oversight of banks decreases bank liquidity creation only for large banks. However, private sector minoring of banks reduces bank liquidity creation only for small banks. These results indicate that a combination of the two supervisory systems may complement one another. Since large banks are complex and difficult to monitor, official supervisory agencies have a beneficial effect on banks' exposure to liquidity risk in such large and complex institutions. In contrast, encouraging private sector monitoring might limit small banks' exposure to liquidity risk.

5.2. Controlling for a country's culture, market conditions, and systematically important financial institutions

Prior studies use Hofstede's classifications of culture to assess the effect of cultural dimensions on the financial system (Kwok and Tadesse, 2006), bank risk-taking (Osei-Tutu and Weil, 2020), and corporate saving behavior (Chen et al., 2017). Following previous studies, we capture aggregate value-based measures of cultural characteristics of a country by including *Uncertainty Avoidance* and *Long-Term Orientation* (Hofstede, 1980). *Uncertainty Avoidance* is an index that measures the degree to which a society deals with uncertainty and ambiguity for the future. *Long-Term Orientation* is an index that measures the degree to which a society deals with the long-term orientation of the society. These two indexes are collected from Hofstede's website.

To control for a country's cultural environment, we drop country fixed effects and instead include *Uncertainty Avoidance* and *Long-Term Orientation*. The estimates of the regressions that control for two dimensions of national culture are presented in Columns 1 and 2 of Table 8. Specifically, we observe that the coefficient on supervisory power remains significantly negative, while being insignificant for the private sector monitoring.[6]

Moreover, interbank markets play a crucial role in the liquidity management of banks. During market turmoil, the interbank markets may dry up as banks tend to hold cash instead of

[6] Controlling for a country's legal origin and a religion does not influence the main results.

lending it to other banks even at short maturities. One of the important lessons that the recent financial crisis taught us was the failure of the most liquid markets in the financial sector (i.e. interbank markets). Stress on the interbank market may make it hard for banks to raise external sources of funds, and thus higher pressure on the interbank market may increase bank illiquidity. Thereby, it might be important to control for the effect of liquidity pressure on the interbank market. To capture the liquidity pressure on the interbank market, we utilize the difference between the one-month interbank rate and the central bank policy rate, with higher values of the spread indicating higher pressure on the interbank market. In addition, a recent study by Berger and Bouwman (2017) documents that monetary policy influences bank liquidity. Hence, to ensure that the findings are not influenced by the macroeconomic environment, market conditions, and the aggregate banking environment, we drop time fixed effects and instead include the central bank's policy rates, and the difference between the one-month interbank rate and the policy rate of the central bank. The results are reported in Columns 3 and 4 of Table 8, and we find that the estimates of the regressions are similar to the main findings.

[Insert Table 8 here]

Finally, in the aftermath of the global financial crisis, bank supervision authorities, regulators, and policymakers have devoted considerable attention to policy measures to address systematically important financial institutions (SIFIs). Given that such large and complex financial institutions can expose higher risks to the financial system, we control for these institutions by including a dummy variable that takes the value of one if the bank is considered to be systemically important in Europe and zero otherwise based on the information provided by Financial Stability

Board. The results are reported in Columns 5 and 6 of Table 8. As can be noted, in general, these results are consistent with previous findings.

5.3. Role of institutional quality, and market incentive

In general, the bare existence of regulatory or supervisory practices does not necessarily mean their application in practice. Given that institutional quality can enhance or impede the implementation of supervisory practices, it is of interest to examine whether the association between bank supervision and liquidity creation is influenced by the quality of the institutional environment. For this purpose, we utilize the World Governance Indicator (*WGI*) complied by Kaufmann et al. (2006) to obtain the quality of the institutional environment in terms of Voice and Accountability, Government Effectiveness, Control of Corruption, Regulatory Quality, Political Stability, Rule of Law. Each one of these indexes ranges from -2.5 to +2.5, with higher values indicating better outcomes. First, following Barth et al. (2013), we capture the quality of the institutional environment as the first principal components indicator of these variables (*PCWGI*), with higher values indicating a higher quality of governance. Next, following Li, Moshirian, Pham, and Zein (2006), we construct an enforcement index (*INFIND*) as the average of the following three dimensions of institutional quality: Control of Corruption, Regulatory Quality, and Rule of Law.

Columns 1-4 of Table 9 provide the results which examine the role of the institutional environment on the relationship between regulatory policies and bank liquidity creation. In particular, Columns 1 and 2 of Table 9 provide the findings of the interaction terms between supervisory power and the institutional quality, while Columns 3 and 4 report the results of the interaction terms between private sector monitoring and the quality of the institutional environment.

Overall, we find that the interaction between official supervisory power, and governance indicator is positive and statistically significant either at the 10 percent level or at the 5 percent level. These findings provide some evidence that the observed negative effect of supervisory power on liquidity creation weakens at higher levels of the nation-wide governance. These results are broadly consistent with Fernández and González (2005), who find that official supervisors with ample power in countries with low accounting and auditing requirements may reduce bank risk-taking behavior. In addition, the results in Columns 3-4 of Table 9 show that the interaction term between private monitoring, the governance indicator is negative and statistically significant at 1 percent level. These results suggest that the effect of private sector monitoring on liquidity creation strengthens at higher levels of the nation-wide governance. The findings indicate that in countries with a higher quality of nationwide governance private monitoring of banks might discourage banks from engaging in risky banking activities. Thus, consistent with previous studies private sector monitoring could have a beneficial effect by the disclosure of accurate information and encouraging private agents to monitor banks.

Overall, these findings suggest that putting all banks under a common regulatory and supervisory umbrella is difficult, as banks in certain environments may expose themselves to higher risks. Therefore, it is important to identify sources of heterogeneity when looking into different regulatory and supervisory policies.

[Insert Table 9 here]

In addition to the quality of the institutional environments, market incentives play an important role in monitoring banks. Disclosing more information about banks does not necessarily imply greater market-based monitoring if the private sector does not have incentives to use this information to monitor banks. Given that the presence of a deposit insurance scheme and greater power and responsibility for the deposit insurer to intervene in the banking sector to rescue ailing banks can undermine incentives of market participants to monitor banks, we construct a new index combining the explicit deposit insurance scheme and the deposit insurer power based on the World Bank's Bank Regulation and Supervision Survey. The constructed market incentive index ranges from 0 to 5, with higher values indicating weaker market incentives for monitoring banks. Specifically, this index measures whether there is an explicit deposit insurance scheme, whether depositors were fully compensated the last time a bank failed, whether the deposit insurance authority has the authority to decide to intervene in a bank, take legal action against bank directors or officials, and has ever taken any legal action against bank directors or officers. A prior study by Cihak et al. (2013) shows that countries that have weaker market incentives for private sectors to monitor banks had a lower crisis probability. Hence, if weaker incentives for the private investor have a lower crisis probability, we expect that the effect of private monitoring on liquidity creation is more pronounced when market incentives are weaker due to the prevalence of the deposit insurance scheme and greater deposit insurer power.

To examine whether the linkage between private sector monitoring and liquidity creation is influenced by the market incentives to monitor and discipline banks, we include an interaction term between private sector monitoring and market incentive index, and re-estimate the baseline model. The result is reported in Column 5 of Table 9. We find that the coefficient estimate of the interaction term between private monitoring and market incentives is negative and statistically significant, indicating that the effect of private sector monitoring on liquidity creation is more pronounced when there are weaker incentives for the private sector to monitor banks. Overall, this finding acknowledges the important role of market incentives for the private sector to monitor and discipline banks. Strengthening the deposit insurance scheme and the deposit insurer's power to intervene in banks may lower the incentives for private investors to monitor banks. Thus, policymakers and supervisors may need to pay special attention to improve market incentives and increase the pool of market participants that have an interest in disciplining banks.

5.4. The effect of bank supervisory policies on bank liquidity risk

Prior studies argue that liquidity creation increases banks' exposure to liquidity risk (e.g., Allen and Santomero, 1998; Allen and Gale, 2004). Given that higher values of liquidity creation show higher bank illiquidity, we use two proxies for bank illiquidity. First, we utilize the net stable funding ratio (*NSFR*) which is the ratio of the available amount of stable funding to the required amount of stable funding proposed by the Basel Committee on Banking Regulation and Supervision (BIS, 2009). The global financial crisis that began in 2007 showed how fast and severely illiquidity can crystallize and some particular sources of funding can evaporate (BIS, 2009). In recognition for banks to address their liquidity management deficiencies, the Basel Committee on Banking Supervision introduced a global framework to strengthen liquidity risk management (BIS, 2009). Among other regulatory standards for elevating the resilience of the financial system, the Basel III accords issued a proposal for the implementation of the net stable funding ratio. Specifically, this ratio is proposed to promote the long-term resilience of banks by requiring banks to fund their activities with more stable funding sources. For consistency with our liquidity creation measure, the inverse of this regulatory ratio (*I_NSFR*) is calculated, with higher values corresponding to higher illiquidity. The *I_NSFR* is the ratio of the required amount of stable funding to the available amount of stable funding. The compositions of assets and liabilities to calculate *I_NSFR* according to Basel III accords (BIS, 2009) are outlined in Table A.1 (*Appendix A*). Second, we calculate the liquidity transformation ratio (*LTR*) which is defined as the ratio of illiquid assets to illiquid liabilities following Deep and Schaefer (2004).[7]

[Insert Table 10 here]

We end our analysis by validating the association between bank supervisory policies and bank illiquidity. For this purpose, we first explore the direct impact of the effectiveness of two supervisory practices on bank liquidity requirements as measured by the inverse of the net stable funding ratio and the liquidity transformation ratio. Columns 1-4 of Table 10 present the results when two liquidity proxies are replaced with the liquidity creation measure. As can be seen from Table 10, we observe a negative association between regulators' supervisory power and market-based monitoring on bank illiquidity, implying the effectiveness of these two supervisory practices on bank liquidity requirements. Overall, these findings indicate that supervisory power and private monitoring may affect bank liquidity creation by mitigating liquidity risk.

Besides exploring the direct effect of supervisory policies on bank liquidity risk, this study tries to provide an integrated approach of the Basel II and Basel III ingredients by examining whether and to what extent the effective supervisory framework and market discipline have a complementary effect on bank liquidity requirements. In this context, Delis and Staikouras (2011)

[7] Illiquid assets are defined as total assets, long-term marketable assets, other assets, and net fixed assets, and illiquid liabilities are defined as time deposits, long-term market funding and equity.

document that effective supervision and market discipline are complementary mechanisms in reducing bank risk. The results in Columns 5 and 6 of Table 10 show that the interaction terms between supervisory power and private monitoring are negative and statistically significant, implying that there is a complementary and amplifying combined effect of these variables on bank illiquidity. Therefore, regulatory authorities need to pay closer attention to the interplay effect between bank supervisory policies, rather than trying to determine separate effects of different types of supervisory practices on bank illiquidity.

6. Conclusions

There is a lack of cross-country evidence on the role of strengthening official supervisory power and private sector monitoring in bank liquidity. In this study, we investigate the linkage between these two supervisory policies and bank liquidity creation. we provide evidence that the traditional approach to bank supervision that entails strengthening official supervisory authorities tends to decrease bank liquidity creation, and bank illiquidity as a whole. In addition, a supervisory strategy that empowers private monitoring of banks by disclosing accurate information to the private sector does not tend to be related to bank liquidity creation. However, such supervisory strategies could lower bank illiquidity, as measured by the inverse of the net stable funding ratio, and liquidity transformation gap ratio.

The empirical findings also show that the quality of the institutional environment and market incentives influences the association between bank supervision and liquidity creation. Given that institutional quality and market incentives condition the relationship between bank supervision and liquidity creation, it is important to identify sources of heterogeneity in the relationship between bank supervisory policies and liquidity creation. Putting all banks under common regulatory and supervisory practices is difficult, as banks operating in certain environments may expose to higher risks.

This paper also explores the direct and combined impact of the effectiveness of the regulators' supervisory power and private sector monitoring on bank liquidity management. We obtain evidence of a negative relationship between regulators' supervisory power, private monitoring, and bank illiquidity. Considering the combined effect of bank supervisory policies on bank illiquidity, we find that regulators' supervisory power and market-based monitoring are complementary mechanisms in reducing bank liquidity risk. Therefore, policymakers and supervisory authorities may need to pay closer attention to the interplay between various regulatory and supervisory policies, rather than attempting to identify the separate impact of different supervisory frameworks on bank liquidity. Overall, the empirical findings provide support for Basel II and Basel III ingredients.

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Table 1. Distribution of banks.

Country	Banks available in Bloomberg	Banks included in the final sample	Total assets of banks in the final sample/total assets of the entire banking sector in the sample (%)	Average official supervisory power	Average private sector monitoring	Average bank liquidity creation
Austria	7	7	1.463	12.02	6.39	0.31
Belgium	6	6	6.497	11.04	7.23	0.18
Bulgaria	5	5	0.017	11.2	7.5	0.17
Croatia	12	7	0.046	11.8	7.87	0.08
Cyprus	4	4	0.163	12	7.78	-0.01
Czech Republic	1	1	0.116	10.59	6.76	0.21
Denmark	23	22	2.025	8.97	9.11	0.14
Finland	2	2	0.044	8	8.76	0.20
France	18	18	20.681	7.89	7.36	0.21
Germany	8	7	11.484	9.24	7.35	0.19
Greece	11	11	1.630	10.46	7.26	0.18
Hungary	1	1	0.122	13.82	8.12	-0.01
Ireland	2	2	1.317	9	9.82	0.45
Italy	25	15	7.961	7.60	7.25	0.24
Lithuania	1	1	0.002	12	8.33	0.07
Luxembourg	1	1	0.436	12.2	7.53	0.13
Malta	4	4	0.047	13.33	8.67	0.14
Netherlands	2	1	0.084	8.46	8.38	0.23
Norway	24	23	1.106	8.60	7.63	0.04
Poland	15	14	0.667	10.46	8	0.13
Portugal	4	4	0.927	13.35	6.35	0.20
Romania	3	3	0.050	9.64	6.21	0.08
Slovakia	4	4	0.094	12.28	6.75	0.21
Spain	10	8	8.119	9.73	8.46	0.19
Sweden	4	4	4.860	6	7	0.27
Switzerland	46	39	5.785	12.88	7.81	0.24
UK	8	6	24.257	9.71	10	0.35

This Table reports the distribution of European publicly traded commercial banks by country.

Table 2. Variable definition and sources.

Variables	Definition	Source
LnGDP	Natural logarithm of gross domestic product.	World Development Indicator (WDI)
LnTA	Natural logarithm of bank total assets.	Bloomberg
ROE	Bank's net income divided by total equity.	Bloomberg
LLP_TL	Bank's loan loss provisions divided by total loans.	Bloomberg
Global Integration	Imports plus exports divided by GDP	World Development Indicator (WDI)
Market Power	Bank *i* total assets in country *j* divided by total assets of the banking sector in country *j*.	Bloomberg
Banking Development	Private credit divided by GDP	Financial Structure Dataset (Beck et al., 2010)
Supervisory Power	The index ranges from zero to fourteen, with higher values indicating greater power. The index is built on fourteen questions. A value of one is added to the index for each answer that is "Yes". 1) Can supervisors meet external auditors to discuss reports without bank approval? 2) Are auditors legally required to report misconduct by managers/directors to a supervisory agency? 3) Can legal action against external auditors be taken by the supervisor for negligence? 4) Can supervisors force banks to change the internal organizational structure? 5) Are off-balance sheet items disclosed to supervisors? 6) Can the supervisory agency order directors/management to constitute provisions to cover actual/potential losses? 7) Can the supervisory agency suspend the director's decision to distribute: 7.1. dividends. 7.2. bonuses. 7.3. management fees. 8) Can the supervisory agency supersede bank shareholder rights and declare the bank insolvent? 9)Does banking law allow a supervisory agency to suspend some or all ownership rights of a problem bank? 10) Regarding bank restructuring & reorganization, can supervisory agency or any other govt. agency do the following: 10.1. supersede shareholder rights. 10.2. remove and replace management. 10.3. remove and replace directors.	Barth et al. (2004, 2006, 2008, 2013)
Private Monitoring	The index ranges from zero to twelve, with higher values indicating more private oversight. The index is composed of the following information: Whether subordinated debt is allowable as part of capital? Are off-balance sheet items disclosed to the public?; Whether bank directors and officials are legally liable for the accuracy of the information disclosed to the public; Whether banks must publish consolidated accounts; Whether banks must be audited by certified international auditors; Whether 100 percent of the largest ten banks are rated by international rating agencies; Whether off-balance sheet items are disclosed to the public; Whether banks must disclose their risk management procedures to the public; Whether accrued, though unpaid interest/principal, enter the income statement while the loan is still non-performing; Whether there is no explicit deposit insurance system and insurance was paid the last time a bank failed.	Barth et al. (2004, 2006, 2008, 2013)
LC	Bank liquidity creation normalized by total assets	Berger and Bouwman (2009)

This table presents definitions and sources of all variables used in this paper.

Table 3. Construction of liquidity creation measure.

Assets	Liquidity Level	Weights
Cash & Near Cash Items	Liquidity Level	-0.5
Interbank Assets	Semiliquid	0
Short-Term Investments	Liquid	-0.5
Commercial Loans	Illiquid	0.5
Consumer Loans	Semiliquid	0
Other Loans	Semiliquid	0
Long-Term Investments	Semiliquid	0
Fixed Assets	Illiquid	0.5
Other Assets	Illiquid	0.5
Customers' Acceptance Liability	Semiliquid	0

Liabilities	Liquidity Level	Weights
Demand Deposits	Liquid	0.5
Saving Deposits	Liquid	0.5
Time Deposits	Semiliquid	0
Other Deposits	Semiliquid	0
Short-Term Borrowings & Repos	Liquid	0.5
Other Short-Term Liabilities	Liquid	0.5
Long-Term Borrowings	Semiliquid	0
Other Long-Term Liabilities	Semiliquid	0
Total Preferred Equity	Illiquid	-0.5
Minority Interest	Illiquid	-0.5
Shareholder Common Capital	Illiquid	-0.5
Retained Earnings & Other Equity	Illiquid	-0.5

This table shows the construction of the liquidity creation measure following Berger and Bouwman (2009) and the corresponding weights for calculating bank liquidity creation are based on Distinguin et al. (2013).

Table 4. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
LC	2,546	0.188	0.152	-0.401	0.841
Supervisory Power	2,546	9.888	2.305	6.000	14.000
Private Monitoring	2,541	7.786	1.219	5.000	11.000
LnTA	2,546	16.156	2.392	9.606	21.643
ROE	2,546	0.102	1.239	-6.601	48.787
LLP_TL	2,546	0.026	0.704	-0.586	34.606
Market Power	2,546	0.151	0.246	0.000	1.000
Global Integration	2,546	0.822	0.381	0.375	3.492
Banking Development	2,546	0.992	0.472	0.064	2.607
LnGDP	2,546	27.328	1.294	22.306	31.040

This table reports the summary statistics of the main regression variables. The sample consists of 220 publicly traded commercial banks from 27 European countries over the period 1996-2013. The definition of the main variables is reported in Table 2.

Table 5. Baseline results.

	(1)	(2)	(3)	(4)
	LC	LC	LC	LC
Supervisory Power	-0.009***	-0.007**		
	(0.003)	(0.003)		
Private Monitoring			-0.008	-0.004
			(0.006)	(0.005)
LnTA		0.002		0.001
		(0.006)		(0.006)
ROE		0.007***		0.007***
		(0.002)		(0.002)
LLP_TL		-0.020***		-0.019***
		(0.001)		(0.001)
Market Power		0.039		0.037
		(0.045)		(0.047)
Global Integeration		0.203***		0.211***
		(0.058)		(0.059)
Banking Development		0.023		0.016
		(0.017)		(0.017)
LnGDP		0.007		0.015
		(0.040)		(0.044)
Constant	0.418***	0.059	0.368***	-0.216
	(0.048)	(1.012)	(0.047)	(1.104)
Observations	2,546	2,546	2,541	2,541
Adjusted R-squared	0.294	0.331	0.293	0.328
Year FE	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes

The table presents the panel regression results examining the impact of bank supervisory policies on liquidity creation. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered by banks are presented in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively. The definition of the main variables is reported in Table 2.

Table 6. Bank capital transimission channel.

VARIABLES	(1) LC	(2) LC
Supervisory Power	-0.006**	
	(0.003)	
Private Monitoring		-0.006
		(0.005)
High Bank Capital	0.090	-0.149*
	(0.069)	(0.080)
Supervisory Power × High Bank Capital	-0.016**	
	(0.008)	
Private Monitoring × High Bank Capital		0.010
		(0.009)
LnTA	-0.001	-0.002
	(0.006)	(0.006)
ROE	0.007***	0.007***
	(0.002)	(0.002)
LLP_TL	-0.018***	-0.018***
	(0.001)	(0.001)
Market Power	0.045	0.048
	(0.043)	(0.045)
Global Integeration	0.209***	0.212***
	(0.056)	(0.057)
Banking Development	0.027	0.014
	(0.017)	(0.017)
LnGDP	-0.004	-0.001
	(0.041)	(0.046)
Constant	0.378	0.258
	(1.040)	(1.177)
Observations	2,546	2,541
Adjusted R-squared	0.361	0.356
Year FE	Yes	Yes
Country FE	Yes	Yes

The table reports the results for analyzing the joint impact of higher bank capital and supervisory practices on liquidity creation. High bank capital is a dummy variable that is equal to one if bank capital ratios are above the 90th percentile, and zero otherwise. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered by banks are presented in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively. The definition of the main variables is reported in Table 2.

Table 7. The role of bank size.

	LC Large	LC Small	LC Large	LC Small
Supervisory Power	-0.007**	-0.007		
	(0.003)	(0.005)		
Private Monitoring			-0.004	-0.028**
			(0.006)	(0.011)
LnTA	-0.003	0.026*	-0.003	0.027*
	(0.008)	(0.014)	(0.008)	(0.014)
ROE	0.007***	0.063	0.007***	0.068
	(0.002)	(0.051)	(0.002)	(0.051)
LLP_TL	-0.022***	-0.017***	-0.022***	-0.017***
	(0.004)	(0.001)	(0.003)	(0.001)
Market Power	0.023	-0.060	0.024	-0.048
	(0.056)	(0.081)	(0.057)	(0.077)
Global Integeration	0.216***	0.092	0.229***	0.045
	(0.071)	(0.073)	(0.073)	(0.083)
Banking Development	0.003	0.044	-0.000	0.028
	(0.031)	(0.028)	(0.032)	(0.021)
lnGDP	0.071*	-0.197***	0.084*	-0.201***
	(0.043)	(0.057)	(0.046)	(0.051)
Constant	-1.509	5.019***	-1.918*	5.225***
	(1.077)	(1.405)	(1.129)	(1.270)
Observations	2,074	472	2,069	472
Adjusted R-squared	0.289	0.515	0.286	0.520
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

This table reports the panel regression results which examine the effect of regulatory policies on liquidity creation by bank size class. Large banks are defined as banks whose total assets exceeding $1 billion, and small banks are defined as banks with total assets of up to $1 billion. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered by banks are presented in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively. The definition of the main variables is reported in Table 2.

Table 8. Controlling for a country's culture, market conditions, and systematically important financial institutions.

	(1) LC	(2) LC	(3) LC	(4) LC	(5) LC	(6) LC
Supervisory Power	-0.008**		-0.007***		-0.007**	
	(0.003)		(0.003)		(0.003)	
Private Monitoring		-0.001		-0.004		-0.004
		(0.005)		(0.005)		(0.005)
LnTA	0.019***	0.020***	0.001	0.001	0.003	0.002
	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)	(0.006)
ROE	0.006***	0.006***	0.007***	0.007***	0.007***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LLP_TL	-0.016***	-0.015***	-0.020***	-0.019***	-0.020***	-0.019***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Market Power	-0.063**	-0.072**	0.041	0.038	0.047	0.045
	(0.031)	(0.032)	(0.047)	(0.049)	(0.045)	(0.046)
Global Integeration	-0.005	-0.013	0.171***	0.173***	0.204***	0.212***
	(0.026)	(0.024)	(0.048)	(0.048)	(0.058)	(0.059)
Banking Development	0.034**	0.018	0.000	-0.006	0.022	0.015
	(0.015)	(0.015)	(0.021)	(0.020)	(0.017)	(0.017)
lnGDP	-0.032***	-0.027***	-0.058	-0.043	0.007	0.015
	(0.007)	(0.007)	(0.038)	(0.041)	(0.039)	(0.043)
Uncertainty Avoidance	-0.001**	-0.001***				
	(0.000)	(0.000)				
Long-term Orientation	0.001***	0.001**				
	(0.000)	(0.001)				
Spread			0.006	0.006*		
			(0.004)	(0.004)		
Policy Interest Rate			0.001	0.002		
			(0.002)	(0.002)		
SIFIs					-0.033	-0.032
					(0.022)	(0.022)

Constant	0.856***	0.679***	1.721*	1.294	0.041	-0.231
	(0.208)	(0.213)	(0.972)	(1.036)	(1.004)	(1.095)
Observations	2,497	2,492	2,237	2,233	2,546	2,541
Adjusted R-squared	0.174	0.167	0.306	0.304	0.332	0.330
Year FE	Yes	Yes	No	No	Yes	Yes
Country FE	No	No	Yes	Yes	Yes	Yes

This table shows the panel regression results for additional analyses. Uncertainty Avoidance and Long-term Orientation are used as a proxy for a county's culture. Uncertainty Avoidance is an index that measures the degree to which a society deals with uncertainty and ambiguity for the future. Long-Term Orientation is an index that measures the degree to which a society deals with the long-term orientation of the society. Spread is the difference between the one-month interbank rate and the central bank policy rate. The policy interest rate is the central bank's policy rate. SIFIs is a dummy variable that takes the value of one if the bank is considered to be systemically important in Europe and zero otherwise. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered by banks are presented in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively. The definition of the main variables is reported in Table 2.

Table 9. Role of institutional quality and market incentive.

	(1) LC	(2) LC	(3) LC	(4) LC	(5) LC
Supervisory Power	-0.005	-0.017***			
	(0.003)	(0.005)			
Private Monitoring			-0.008*	0.044**	0.014
			(0.004)	(0.017)	(0.010)
PCWGI	-0.051**		0.059***		
	(0.022)		(0.022)		
ENFIND		-0.270***		0.145*	
		(0.086)		(0.080)	
Supervisory Power x PCWGI	0.002*				
	(0.001)				
Supervisory Power x ENFIND		0.009**			
		(0.005)			
Private Monitoring x PCWGI			-0.010***		
			(0.003)		
Private Monitoring x ENFIND				-0.036***	
				(0.011)	
Market Incentive					0.062**
					(0.028)
Private Monitoring x Market Incentive					-0.010**
					(0.004)
Constant	-1.123	-1.257	-0.211	-0.901	0.204
	(1.090)	(1.042)	(1.081)	(1.066)	(1.022)
Observations	2,175	2,175	2,172	2,172	2,541
R-squared	0.334	0.338	0.339	0.343	0.347
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes

This table reports the panel regression results which examine the role of institutional quality environments and market incentives on the relationship between supervisory policies and liquidity creation. The quality of institutional characteristics is obtained from Kaufmann et al. (2006). PCWGI is calculated as the first principal components indicator of six dimensions of governance, with higher values indicating a higher quality of governance. ENFIND is calculated as the average of the following indexes: Control of Corruption, Rule of Law, and Regulatory Quality. The market incentive is an index that combines the explicit deposit insurance scheme and the deposit insurer power based on the World Bank's Bank Regulation and Supervision Survey. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered by banks are presented in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively. The definition of the main variables is reported in Table 2.

Table 10. The effect of bank supervisory policies on bank liquidity risk.

	(1) I_NSFR	(2) LTR	(3) I_NSFR	(4) LTR	(5) I_NSFR	(6) LTR
Supervisory Power	-0.032*	-0.102***			0.252*	0.605***
	(0.017)	(0.039)			(0.130)	(0.192)
Private Monitoring			-0.090**	-0.230***	0.267**	0.662***
			(0.045)	(0.069)	(0.134)	(0.223)
Supervisory Power × Private Monitoring					-0.037**	-0.092***
					(0.017)	(0.025)
LnTA	0.071***	-0.153**	0.068***	-0.169***	0.071***	-0.161***
	(0.024)	(0.060)	(0.024)	(0.060)	(0.023)	(0.059)
ROE	0.007	0.246*	0.008	0.249*	0.008	0.248*
	(0.007)	(0.136)	(0.006)	(0.137)	(0.006)	(0.135)
LLP_TL	-0.026***	-0.121***	-0.024***	-0.117***	-0.026***	-0.123***
	(0.005)	(0.017)	(0.004)	(0.017)	(0.005)	(0.017)
Market Power	-0.303	-0.198	-0.300	-0.031	-0.316	-0.082
	(0.208)	(0.421)	(0.210)	(0.415)	(0.212)	(0.412)
Global Integration	0.581**	2.317***	0.440*	1.971**	0.474*	2.021**
	(0.281)	(0.835)	(0.231)	(0.820)	(0.253)	(0.845)
Banking Development	-0.181	-0.255	-0.233*	-0.399	-0.121	-0.104
	(0.128)	(0.264)	(0.129)	(0.253)	(0.124)	(0.270)
lnGDP	0.123	-0.521	0.167	-0.413	0.226	-0.287
	(0.211)	(0.553)	(0.225)	(0.506)	(0.236)	(0.488)
Constant	-3.636	18.541	-4.446	16.465	-8.544	6.985
	(5.577)	(14.609)	(5.852)	(13.297)	(6.439)	(13.424)
Observations	2,546	2,546	2,541	2,541	2,541	2,541
Adjusted R-squared	0.150	0.216	0.152	0.219	0.155	0.228
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Country FE	Yes	Yes	Yes	Yes	Yes	Yes

This table shows the results of the panel regressions examining the effect of supervisory policies on bank liquidity risk. The I_NSFR is the inverse of the net stable funding ratio (BIS, 2009) and LTR is the liquidity transformation gap ratio (Deep and Schaefer, 2004). The I_NSFR and LTR are used as liquidity risk proxies. The last two columns of this table report the estimation results on the combined effect of supervisory power and private monitoring on bank illiquidity. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered by banks are presented in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively. The definition of the main variables is reported in Table 2.

Appendix A

Table A.1. Calculation of the net stable funding ratio.

Assets	Corresponding definition of BIS	Weights
Required amount of stable funding		
Cash and near cash items	Cash	0
Interbank assets	Loans to financial entities having effective maturities of less than one year	0
Marketable securities and other short-term investments	Securities with effective remaining maturities of less than one year	0
Commercial loans	All other assets	1
Consumer loans	Loans to retail clients having residual maturity of less than one year.	0.85
Other loans	All other assets	1
Long-term investments	Unencumbered listed equity securities or unencumbered corporate bonds rated at least A- with an effective maturity of greater than 1 year)	0.5
Fixed assets	All other assets	1
Other assets	All other assets	1
Customer acceptances	Unencumbered listed equity or nonfinancial senior unsecured corporate bonds rated at least A- (with remaining maturity > 1 yr)	0.5

Liabilities	Corresponding definition of BIS	Weights
Available amount of stable funding		
Demand deposits	Retail deposits and/or term retail deposits with residual maturities of less than one year	0.7
Saving deposits		0.7
Time deposits	Other liabilities with effective maturities of one year or greater	1
Other term deposits	Other liabilities with effective maturities of one year or greater	1
Short-term borrowings	All other liabilities and equity categories not included in the above categories	0
Other short-term liabilities	All other liabilities and equity categories not included in the above categories	0
Long-term borrowings	Other liabilities with effective maturities of one year or greater	1
Other long-term liabilities	Other liabilities with effective maturities of one year or greater	1

Subordinated debentures	Total amount of capital, including both Tier 1 and Tier 2, and total amount of any preferred stock not included in Tier 2 that has an effective maturity of one year or greater	1
Preferred equity		1
Minority interests		1
Shareholder common capital		1
Retained earnings		1

This table presents the balance sheet weights used to calculate the net stable funding ratio based on Basel III accords (BIS, 2009).