Bank liquidity creation and systemic risk

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.

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Keywords: bank liquidity creation, systemic risk, systemic linkage, tail risk

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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, 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, 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; Fungacova, Turk and Weill, 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 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, Fungacova and Weill (2015), Berger and Sedunov (2017), and Davydov, Fungacova and Weill (2018). These studies show that liquidity creation is positively related to economic output and growth as well as business cycle fluctuations. Horvath, Seidler and Weill (2014), Berger, Bouwman, Kick and Schaeck (2016), Diaz and Huang (2017), and Fungacova, Weill and Zhou (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 (Horvath 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; Fungacova 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.

[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).

Brunnermeier, Dong and Palia (2012), Pais and Stork (2013), Mayordomo, Rodriguez-Moreno and Pena (2014), Calluzzo and Dong (2015), Iqbal, Strobl and Vahamaa (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-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

[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.

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

[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.

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

[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.

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:

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

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:

$$\tau_i(\alpha) = \Pr \left(R_i < -VaR_i(\alpha) \,\middle|\, R_m < -VaR_m(\alpha)\right). \tag{3}$$

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^T can 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:

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

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

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.

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

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 Vahamaa (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 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.

(Insert Table 1 about here)

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*.

(Insert Table 2 about here)

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 assets* (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:

$$\log\left(Risk_{i,t}\right) = \alpha + \beta Liquidity\ creation_{i,t\text{-}1} + \gamma\left(Bank\text{-}specific\ controls\right)_{i,t\text{-}1} + \omega\left(Bank\ fixed\text{-}effects\right)_{i,t} + \varphi\left(Time\ fixed\text{-}effects\right)_{i,t} + \varepsilon_{i,t} \quad (6)$$

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.

(Insert Table 3 about here)

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 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.

(Insert Table 4 about here)

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.

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.

(Insert Table 5 about here)

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 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-Prescot (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.

(Insert Table 6 about here)

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 stand-alone 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.

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 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.

(Insert Table 7 about here)

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 funding 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.

(Insert Table 8 about here)

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.

(Insert Table 9 about here)

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 Engle (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.

(Insert Table 10 about here)

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.

(Insert Table 11 about here)

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 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

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

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* 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.

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Table 1. Descriptive statistics.

	Mean	Median	St.dev.	Min	Max	No. of obs.
Dependent variables:						
Systemic risk	1.013	0.984	0.38	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 1st and 99th percentiles.

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)
Liabilitity-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.

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)
Liabilitity-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 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.

Table 5. The role of liquidity creation in the system.

Panel A: Liquidity creation of other banks in the system

	Systemic risk	Tail risk	Systemic linkage	Systemic risk	Tail risk	Systemic linkage
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
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	Tail risk	Systemic linkage
	Model (1)	Model (2)	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 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

Table 6. High vs. low liquidity creation.

	Systemic risk	Tail risk	Systemic linkage
	Model (1)	Model (2)	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.

Table 7. The role of bank size.

Panel A: Univariate tests

	Small banks	Large banks	Difference
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	Medium-sized banks	Large banks
	Model (1)	Model (2)	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.

Table 8. The role of bank funding structure.

	Low deposits to assets ratio	Medium deposits to assets ratio	High deposits to assets ratio
	Model (1)	Model (2)	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	0.08	-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.

Table 9. The role of bank capital structure.

	Low capital ratio	Medium capital ratio	High capital ratio
	Model (1)	Model (2)	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	-3.22 ***	-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	-0.21
	(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.

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.

Table 11. Liquidity creation and systemic risk in different subperiods.

Panel A: Pre-crisis period

	Systemic risk	Tail risk	Systemic linkage
	Model (1)	Model (2)	Model (3)
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	Tail risk	Systemic linkage
	Model (1)	Model (2)	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	Tail risk	Systemic linkage
	Model (1)	Model (2)	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 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.

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