Bank Liquidity Creation and Technological Innovation[☆]

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September 18, 2019

Abstract

This paper examines the association between bank liquidity creation and technological innovation. Using a comprehensive measure of bank output and innovation output, I find that bank liquidity creation decreases technological innovation. This is robust to using the instrumental variable approach and several robustness checks. Innovation increases among firms that have above-median asset tangibility. Using state-industry-level innovation output, I also show that the observed negative relation between bank liquidity creation and technological innovation is mainly driven by manufacturing and finance industry. Further analysis reveals that the relation between bank liquidity creation and technological innovation is asymmetric. Overall, the results in this paper stress the fundamental role played by innovation in the finance-growth nexus, and have important implications.

JEL classification: G20, G21, G28, G32, O31
Keywords: liquidity creation; financing; banks; innovation

[☆] I thank Jan Bartholdy, Timo Korkeamäki, participants at the NTNU workshop in Norway (September 2), International Finance and Banking Society (June 2019), Finnish Summer Graduate School of Finance Workshop (June 2019), Nordic Finance Network Workshop (May 2019), and research seminar participants at the University of Vaasa (March 2019) for helpful discussions and suggestions.

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1. Introduction

It has been long argued that there is a strong connection between finance, innovation and economic growth.[1] Financial intermediation has a crucial role to play in promoting or hampering long-term economic growth depending on the evolutionary process generating innovation (see e.g. Dosi, 1988; Fagiolo, Giachini, and Roventini, 2017). Well-functioning financial system may improve the probability of successful innovation and thus promote economic growth (see e.g. Schumpeter,1911; King and Levine, 1993b).[2] On the contrary, an increase in banking credit may dampen the economic growth as documented by Schularick and Taylor (2012) and Kaminsky and Reinhart (1999).

In this paper I examine how banks affect technological progress by focusing on bank liquidity creation. On the one hand, the focus on technological innovation is reinforced by the fact that innovation is the main channel through which financial function may affect economic growth because innovation can lead to higher productivity (Solow 1957). The growth models of Aghion and Howitt (1992), Grossman and Helpman (1991), and Romer (1990) show that financial system can affect steady-state growth by changing the rate of technological innovation. In addition to long-run economic growth, corporate innovation is a source of competitive advantage for firms (Porter 1992). On the other hand, liquidity creation is a core economic function of banks and it dated back to Adam Smith (1776). Bank liquidity creation is a comprehensive measure of bank total output in the economy which includes assets, liabilities, equity and bank's off-balance sheet activities. Each components of liquidity creation such as bank loans, transaction deposits, off-balance sheet derivatives, and guarantees have different theoretically-driven weights based on ease, cost and time for customers to obtain liquid funds from the bank. Previous papers by Berger and Sedunov (2017), and Fidrmuc, Fungacova and Weil (2015) link bank liquidity creation to economic growth. However, innovation is an important channel to link finance to growth, and the nexus of finance and innovation is central to the process of economic growth (Schumpeter,1911).

My contribution in this paper is two-fold. First, I seek to fill the gap in the finance-growth nexus literature by presenting the first empirical examination of whether bank liquidity creation

[1] See e.g. Fagiolo, Giachini and Roventini, 2017; Levine, 2005; Levine, 1997; King and Levine, 1997a; King and Levine, 1997b; Schumpeter,1911.

[2] Schumpeter (1911) highlights the important role of financial intermediaries in technological innovation and the process of economic growth. In particular, he notes that "The banker, therefore, is not so much primarily a middleman ... He authorizes people in the name of society ... (to innovate).".

affect technological innovation. Second, I aim to expand the limited but growing empirical literature on bank liquidity creation. While some recent studies look at how bank liquidity creation affects economic growth, to the best of my knowledge, there is no paper examines how bank liquidity creation is related to innovation productivities.

Diamond and Dybvig's (1983) model highlights that banks can offer liquid deposits to investors and undertake a mixture of liquid, low return investment to satisfy demands on deposits and illiquid, high-return investments. By offering liquid deposits to savors and choosing a mixture of liquid and illiquid investments while facilitating long-term investments with high returns, banks can provide liquidity to the economy. Aghion, Angeletos, Banerjee and Manova (2004) show how firms' ability to access financing can influence innovation and long-run growth.

Technological innovation is characterized by asymmetrical information and moral hazard problems (Hall, 2002; Akerlof, 1970). Banks can ameliorate information asymmetry and transaction costs, and thus they influence saving rates, investment decisions, technological innovation and ultimately long-run growth rate. Technological progress may not occur without liquidity transformation role of banks, by transforming liquid liabilities such as demand deposits with illiquid assets such as investments in illiquid production processes, and long-term loans. Liquidity may affect the rate of technological change if high commitment of resources to research and development in the long-term promote technological innovation.

Technological progress also requires long-run monitoring and commitment of capital. However, savors do not like to lose control of their money for a long time. If financial intermediaries do not augment liquidity of long-term investment, less investment is likely to occur. Banks can increase investment in high-return and illiquid assets such as innovative projects, and thus promote growth in the long-run. This shows the importance of financial intermediaries because they enhance liquidity in the economy and channel saving to finance the most productivity-enhancing activities (King and Levine, 1993b; Bencivenga and Smith, 1991). Therefore, creation of liquidity as a major function of banks is important not only for innovation productivity, but also for economic growth. However, excessive level of bank liquidity creation might also be detrimental to economic growth because the amount of liquidity created by banks can be an indicator of future financial crisis (Berger and Bouwman, 2017). In addition, banks' desire for risk increases during economic booms, and thus they may start financing undesirable high-risk projects due to adverse selection. This misallocation of capital may lower productivity, and lead to more default and less growth.

Bank 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). However, the process of liquidity creation reduces the liquidity of banks and exposes them to different types of risks, liquidity crunches, and bank runs (Diamond and Dybvig, 1983; Kashyap, Rajan and Stein 2002; Berger and Bouwman, 2009). From a macroprudential perspective, excessive level of bank liquidity creation may cause financial system instability and financial crises as documented by Acharya and Naqvi (2012), and Berger and Bouwman (2017). Therefore, there is a trade-off between high liquidity creation and economic growth on the one hand, and high liquidity creation and financial system stability on the other hand.

The association between bank liquidity creation and technological innovation might be unclear ex ante. One might think that since bank liquidity creation is positively associated with GDP, the provision of liquidity might also be positively associated with technological innovation, as technological innovation is a main driver of economic growth due to its effect on productivity growth and aggregate growth. However, if excessive level of liquidity creation is associated with financial crises and financial system instability, then high level of bank liquidity creation might be associated with lower technological innovation since it may dampen long-run growth.

For a long time, liquidity creation was only a theoretical concept[3], and thus it received little attention in prior empirical research. In 2009, Berger and Bouwman developed a comprehensive measure of bank output which is consistent with the financial intermediation theory. According to the modern theory of financial intermediation, banks can create liquidity on their balance sheets by financing relatively illiquid assets such as long-term loans with relatively liquid liabilities such as demand deposits (Bryant, 1980; Diamond and Dybvig, 1983), and they can also create liquidity off their balance sheets through loan commitments and other kinds of claims such as standby letters of credit (Kashyap et al., 2002). Berger and Bouwman’s liquidity creation measures are the weighted sum of bank’s all on- and off- balance sheet activities. To summarize briefly, positive weights are given to illiquid assets, and liquid liabilities, and negative weight are given to liquid

[3] For example, see e.g. Diamond and Dybvig, 1983; Holmstrom and Tirole, 1998; and Kashyap, Rajan, and Stein, 2002.

assets, illiquid liabilities and equity. The weights assigned to off-balance sheet activities are also similar to on-balance sheet activities. Positive weights are consistent with the theoretical notion that by creation liquidity banks actually take something illiquid from the public and in turn give the public something liquid. Negative weights are also in line with the theoretical notion that banks can destroy liquidity by financing liquid assets with illiquid liabilities or equity. The construction of the Berger and Bouwman (2009) bank liquidity creation measures is outlined in Appendix 1, Table A.1.

To assess the effect of bank liquidity creation on technological innovation, I use Berger and Bouwman's preferred measure of bank liquidity creation as well as their other two measures. Specifically, I use the measure of liquidity creation which incorporates all bank on-balance sheet and off-balance sheet activities (total LC), the measure which only includes on-balance sheet activities ("LC_OnBS"), and also the measure which only includes off-balance sheet activities (LC_OffBS). Following existing innovation literature, I use patents and citations as measures of innovation output. Using annual state-level data on bank liquidity creation and innovation output from 1984 to 2006, I find that bank liquidity creation is negatively associated with technological innovation. This result is robust to controlling for state-level conditioning variables, banking environment and regulation, state-industry-level labor force composition, state fixed effects and year fixed effects. The result also holds when using the instrumental variable approach, and is robust to a verity of robustness checks. In additional tests, I document that the observed negative relationship is mainly driven by finance and manufacturing industry.

When splitting liquidity creation by bank size class, I find a positive, and significant effect of bank liquidity creation on the quantity of innovation for large banks, and insignificant effect on the quality of innovation. However, this relationship is negative and significant for small banks. Further analysis reveals that bank liquidity creation has a positive effect on innovation output by firms that have above-median tangible assets.

In addition, I examine weather bank liquidity creation may affect innovation output through bank lending channel. When bank lending channel is introduced in the regression, the impact of bank liquidity creation on innovation productivity becomes smaller, and its significance level drops.

Finally, I investigate whether and how the effect of bank liquidity creation on technological innovation is non-linear in the form of asymmetry. To answer this question, I first compare the effect of negative and positive shocks of bank liquidity creation on innovation productivity, and I find that the effect of bank liquidity creation on innovation output is asymmetric. Second, I examine the effect of bank liquidity creation on innovation over the business cycle, and I find that there is a positive but insignificant relation between bank liquidity creation and innovation output during economic recessions. However, this relationship is negative and significant during economic expansions. Overall, the results are consistent with the recent empirical literature suggesting a complex relationship exists in finance-growth nexus.

My paper builds upon two recent strands of literature. First, my paper is related to the emerging literature on finance and innovation. [4] Few recent papers examine the impact of credit market development on technological innovation. Using the interstate banking deregulation in the US, Amore, Schneider and Žaldokas (2013) show that banking development has a positive influence on the technological progress, while Cornaggia, Mao, Tian and Wolfe (2015) find that banking competition has a negative impact on technological innovation. In addition, Benfratello, Schiantarelli and Sembenelli (2008) find that local banking development has a positive impact on the process innovation, but it does not have a robust impact on the product innovation. Hsu, Tian and Xu (2014) also document that credit markets discourage innovation in industries that are more dependent to external finance and that are high-tech intensive. In addition, Laeven, Levine and Michalopoulos (2015) show that technological innovation and economic growth eventually stop without financial innovations that enhance the screening of technological entrepreneurs. However, this literature has not focused on bank liquidity creation, and only considered bank credit which only considers a part of banks' function, and it cannot measure the total bank output in the economy.[5] Bank's off-balance sheet activities account for about fifty percent of all liquidity creation in the US (Berger and Bouwman, 2009). For example, off-balance sheet guarantees, and derivatives allow firms to expand their investment and capital expenditure without facing significant price risks. Hence, neglecting bank's off-balance sheet activities may fail to capture a major part of bank output.

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

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

Second, my paper is also related to the relatively small but growing body of literature on bank liquidity creation. The role of bank liquidity creation for the macroeconomy and economic growth is empirically examined by 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 the economic output as well as business cycle fluctuations. Horwath, 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. The findings indicate the level of liquidity creation is higher for banks with lower capital ratios and stronger corporate governance mechanisms (Horwath et al., 2014; Diaz and Huang, 2017). Furthermore, bank liquidity creation is affected by regulatory interventions, bailouts, and deposit insurance systems (Berger et al., 2016; Fungacova et al., 2017), but is largely unaffected by monetary policy (Berger and Bouwman, 2017).

The results in this paper stress the fundamental role played by innovation in the finance-growth nexus, and have important implications. Specifically, the results show that more stringent macro-prudential regulation on bank liquidity could have a positive impact not only on financial stability, but also on the long-run performance of the economy. The reason is that when banks excessively create liquidity, they not only make themselves illiquid while providing more liquidity for the economy, but they also may harm economic growth because firms may perform too much exploitation of the technological space which leads to waste of resources, due to producing many unsuccessful innovative projects. Consistent with this view, Acemoglu, Aghion, and Zilibotti (2003) document that the importance of innovation increases as a country approaches the technological frontier, and they argue that if an economy exploits existing technologies, it may end up in a non-convergence trap.

Second, government policies toward financial systems may have an important effect on innovative activities and long-run growth. Therefore, authorities and banking supervisors should pay closer attention to total bank output and the size of the banking sector. Also, they should improve the measures that strengthen the quality of finance. Even though previous researchers find that bank liquidity creation is one of the determinants of economic growth, if high level of liquidity creation has a negative impact on innovation in a particular situation, then other growth-enhancing strategies need to be implemented by authorities to maintain long-run economic benefits.

The rest of paper proceeds as follows. Section 2 the data and variable constructions. Section 3 presents the methodology and baseline results and the results of instrumental variable estimation. Section 4 presents robustness tests. Finally, the last section summarizes the findings and concludes the paper.

2. Data

2.1. Measuring innovation

To measure innovation activities, I collect patents and citations data from the NBER Patent and Citation database created by Hall, Jaffe, and Trajtenberg (2001) for the period 1984-2006. The database provides the annual information on patent assignee names, the number of patents, the number of citations for each patent, a paten's application year, a patent's grant year, etc. Following Hall, et al. (2001), and Grilinches, Pakes and Hall (1988), a patent's application year is used instead of its grant year, since the actual time of innovation is better captured by the application year.

I construct two measures of firm's innovation output based on the information available in the NBER database. The first measure employed in this study is the number of patent applications a firm files in a year that are eventually granted. Even though it is straightforward to calculate, the first measure cannot differ groundbreaking innovations from incremental technological discoveries (Trajtenberg, 1990). As a second measure, I use the citation count each patent receives in subsequent years to further assess a patent's influence. While the number of citations captures the economic importance of innovation output, the number of patents captures the quantity of innovation output. Following the innovation literature, I use both measures of innovation output generated in the three subsequent years to reflect the long-term nature of investment in innovation. This approach also mitigates the impact of idiosyncratic shocks which can distort innovation productivity in any year.

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

[Table 1]

To match patents to the firm's GVKEY, I merge the patent data with Compustat data using the bridge file provided by the NBER database. Following the innovation literature, for companies which have no patent information available in NBER database I set the number of patents to zero. I drop assignees that are either universities, individuals, or governments.[6]

In the baseline analysis, I convert patents and citations generated by all firms to the state level and run the panel regressions with fixed effects on state-year observations. In later test, to address the potential endogeneity concern in the regression, I also perform two-stage least square (2SLS) approach. In further analysis, I also explore the possible mechanism, channels and the non-linear relation between bank liquidity creation and innovation output over business cycles.

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

2.2. Measures of bank liquidity creation

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

I use quarterly data on bank liquidity creation.[7] To match the frequency of the patent and citation data, I calculate all liquidity creation measures at annual frequency by taking the annual average of each liquidity creation measure for each bank in each year and then I aggregate these data to state level. In further analyses, I also compute the liquidity created by small and large banks. On-balance sheet liquidity creation (LC_OnBS) and off-balance sheet liquidity creation (LC_OffBS) are also computed using Berger and Bouwman (2009).

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

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

Most banks operate in a single state. However, there are some cases where banks also operate in multi-states. In the single-state cases, I simply aggregate the liquidity creation measures for all banks in the state. For banks which operate in multiple states, I assume the liquidity creation is geographically distributed according to the deposits of the bank. For this purpose, I extract the data from The FDIC's Summary of Deposits (SoD) which reports the amount of deposits held by banks in each office in the US.[8] As a robustness check, I only include single-state banks to mitigate the attenuation bias generated from the measurement error. To minimize the effect of outliers on the bank liquidity creation measures, I winsorize the measures at 0.5st and 99.5th percentiles of their empirical distributions.

2.3. Control variables

I include different control variables following the innovation literature. To control for the innovation input, I use logarithm of one plus R&D spending (LnRD). Return on assets (ROA), and cash holding (cashHolding) are controlled for the role of internal resources in financing innovation (Himmelberg and Petersen, 1994). In addition, firm leverage and capital expenditure are included to control for the role of financial dependencies. I also control for time-varying state's economic activity. In particular, I include annual growth rate of gross state product (GDP), and I estimate the state economy's comovement with the rest of US (Correlation) using monthly values of coincident indexes from 1984 to 2006.[9] To control for local output, I include the annual growth rate in personal income (PI) in the state.

In addition, Rice and Strahan (2010) construct an index of interstate branching restrictions. As described in their paper, the Interstate Banking and Branching Efficiency Act (IBBEA) allowed states to employ interstate branching for the first time since 1927, letting banks to expand across states. Specifically, states could set regulations on interstate branching based on four provisions as follows: the minimum age of the target institution, de novo interstate branching, the acquisition of individual branches, and a statewide deposit cap. The Rice and Strahan Index (RSI) adds one to the index when a state adds any of the four restrictions just described. Thus, RSI ranges from 0 to 4, with zero indicating that the state is most open to out of-state entry, and four indicating that the state is most restrictive to out of-state entry.

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

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

Following Rice and Strahan (2010), I control for interstate branching restrictions as a proxy for bank competition and state-level banking environment in the baseline model (Cornaggia, Mao, Tian and Wolfe, 2015). Shenoy and Williams (2017), update RSI to 2008. According to their paper, in 2005 Montana permitted interstate de novo branching by out-of-state banks, and in 2006, Mississippi permitted interstate branching through the acquisition of single branches or other portions of an institution and through de novo branching. Therefore, I update the value of RSI for these two states after 2004.

Table 2 provides summary statistics of the variables used in this study. The sample consists of annual state level observations for 50 states of the US over 1984-2006. A state in my sample has, on average, 1,962 granted patents in the next three years, and these patents gain a total of 28,976 citations. At the firm-state level, firms have ROA of 8.2%, leverage of 11.7%, CAPEX of 4.6%, cash holding of 5.3%, and the average value of SRI is 3.3 in the sample.

[Table 2]

3. Methodology and empirical results

3.1. Panel regression

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

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

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

In further analyses, I investigate whether bank liquidity creation influence innovation by firms that have above-median asset tangibility. I also examine the effect of bank liquidity creation on innovation by bank size class. Furthermore, I explore whether the relation between bank liquidity creation and firms' innovation output is asymmetric.

In additional tests, I employ bank equity as an instrument and perform 2SLS approach to address endogeneity concern regarding my key independent variable (Total LC). One possible mechanism that helps explain the overall relation between bank liquidity creation and innovation is through bank-dependent industries. For this purpose, first I control for a vector of state-industry-level labor force composition for various industry segments following Morgan, Rime and Strahan (2004). Specifically, I calculate the labor force composition for the following industries: Manufacturing, Construction, Finance, Mining, Service, Government, Trade, and Transportation Second, I replace Lnpat and Lncite with the number of patents and citations generated in different industry segments. In particular, I aggregate all patents and citation across all firms in the same two-digit SIC code industry in each state and in each year. Finally, I investigate through which banking credit channels bank liquidity creation may affect technological productivity.

3.2 Empirical Results

Table 3 reports the first set of regression results. To ensure that the results are not driven by spurious correlation between the various independent variables, columns 1 and 3 of Table 3 only include state and year fixed effects as control variables. Columns 2 and 4 show the results for my full model. In columns 3 and 4, I replace the dependent variable with the natural logarithm of the number of citations, Lncite.

From Table 3, I find that the coefficient estimates on liquidity creation are negative and statistically significant across all specifications. For example, the coefficient estimates in full models in columns 2 and 4 suggest that a one standard deviation increase in bank liquidity creation is related to an economically significant 1.5% and 1.6% decrease in the quantity and quality of innovation respectively.[10] The result is consistent with the finding of Acemoglu et al. (2003), arguing that innovation is more important than imitation as a country approaches the technology frontier. Fagiolo et al. (2017) also show that excessive level of financing innovative projects may tilt the balance between exploration and exploitation of the technological space by firms and result

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

in waste of resources due to producing many unfruitful innovative projects. Moreover, Levine (2005) finds that an increase in financing can hurt the real economy, and hamper economic growth beyond a threshold.

I also find that a greater innovation input (LnRD) is associated with more innovation output. The positive and significant effect of RSI on technological innovation is also consistent with previous findings of Cornaggia et. al. (2015), implying the interstate branching deregulation (i.e. banking competition) negatively affects innovation. In addition, I find a positive association between firm's profitability and its innovation output.

[Table 3]

For further analyses, to investigate the effect of on- and off-balance sheet liquidity creation on technological innovation, I replace total liquidity creation with on- and off-balance sheet liquidity creation. The results are reported in Table 4. Even though on-balance sheet liquidity creation does not explain the cross-sectional variation in technological innovation, bank's off-balance sheet activities have a negative impact of either quantity or quality of innovation. Using the coefficient from the model in column 4 of Table 4, I find that a one standard deviation increase in bank's off-balance sheet liquidity creation is associated with almost 1.6% decrease in the quality of patents. This result shows the important role of banks' off-balance sheet activities. Off-balance sheet guarantees, and derivatives not only allow firms to easily expand their activities, but also allow firms to expand by hedging market prices (Stulz, 2003). For example, loan commitments and standby letter of credit allow firms to plan their expenditure and investment (Boot et al., 1993), while commercial papers can act as back-up for capital market financing.

[Table 4]

3.2.1. Asset Tangibility

Innovative firms may tend to have few tangible assets, and therefore banks might be less willing to lend against the security of intangible assets. Due to information asymmetry, low redeployability, and higher uncertainty in liquidation value, intangible assets might tend to represent poor collateral (see e.g. Williamson, 1988; Shleifer and Vishny, 1992). Asset-backed lending may solve the moral hazard problem in lending, and detect firm insolvency much faster than other types of lending. Therefore, banks might provide greater funding to those firms with more tangible assets. In this section, I explore whether innovation output by firms with more tangible assets is affected by bank liquidity creation. To answer this question, I aggregate innovation output by firms which have above-median asset tangibility in each state. Asset tangibility is defined as Property, Plant & Equipment divided by book value of total assets. The results are reported in Table 5. Interestingly, I observe a positive and significant effect of liquidity creation on quantity of innovation productivity for firms with above-median tangible assets. While not statistically significant, I observe a qualitatively similar pattern for quality of innovation output. These findings suggest that bank liquidity creation enhance innovation by firms that have above-median asset tangibility.

[Table 5]

3.2.1. Large vs Small Banks

The banking literature suggests that large banks provide credit to large firms which are less bank-dependent and small banks provide loans to small businesses because, unlike larger firms, they have limited access to public debt and equity. Therefore, it is interesting to examine the effect of bank liquidity creation on technological changes by bank size class. For this purpose, I split my sample of banks into two subsamples using a cutoff point of $1 billion in gross total assets following Berger and Sedunov (2017).[11] Banks with gross total assets exceeding $1 billion are considered as large banks, and banks with gross total assets of up to $1 billion are considered small banks. I re-estimate the baseline model, but I replace total liquidity creation measure with the two size-based liquidity creation. The results are presented in Table 6. From Table 6, I find that the coefficient estimates on total liquidity creation by small banks are negatively associated with quantity and quality of technological innovation. However, the coefficient on liquidity creation by large banks is positive and statistically significant for the patents, while it is insignificant for citations. Using the coefficient estimates in column 1, a one standard deviation shift in the total liquidity created by small banks is associated with a 1.9% decrease in the quantity of patents, while for a same increase, using the coefficient on total bank liquidity creation for large banks, the patents increases by 1.03% over the sample mean. This result shows that large bank liquidity creation may matter more because large bank may spur technological innovation.

[Table 6]

3.2.2. Endogeneity Concerns

[11] $1 billion is the typical cutoff point for small and large banks in the banking literature (see e.g. Carter and McNulty, 2005; Berger and Black, 2011)

To check whether the main results are not driven by endogeneity concerns, I re-estimate the baseline model using a two-stage least squares (2SLS) approach. For instance, banks might grow more in the states with higher technological innovation, or shrink in states with low innovation productivity. Following Berger and Sedunov (2017), I use bank equity per capita as an instrumental variable. I believe that bank capital satisfies the exclusion restriction, because it is implausible that bank capital affect innovation outside of liquidity creation. Bank equity capital should affect innovation through lending, deposits, off-balance sheet activities which are all the components of bank liquidity creation.

Table 7 represents the results for the 2SLS model. Column 1 reports the first-stage results, and columns 2 and 3 show the results for the second-stage. From columns 1, I find that bank equity per capital positively predict bank liquidity creation documented by Donaldson, Piacentino, and Thakor (2018). From columns 2 and 3, I find that the coefficient estimates on total LC are still negative and statistically significant after tackling the endogeneity concern. Using theses coefficients, I estimate that a one standard deviation increase in total bank liquidity creation is associated with almost a 1.6% and 1.1% decrease over mean of the quantity and quality of innovation respectively.

To further assuage the endogeneity problems, following the methodology of Granger (1969) I also perform reverse causality. It is important to note that the Granger causality does not address causation, but it only addresses predictability. In this analysis, I run regressions of liquidity creation on innovation variables and liquidity creation, using the first lags, and control variables. The results are shown in columns 4 and 5 of Table 7. The results indicate that there is not any evidence that innovation Granger-cause bank liquidity creation.

[Table 7]

3.2.3. Mechanism and Credit Channel

I explore a possible mechanism through which bank liquidity creation may affect innovation output. Specifically, I examine whether overall relation between bank liquidity creation and innovation is through bank-dependent industries, and how overall relation between bank liquidity creation and innovation differs depending on the industry-level reliance on external finance. For this purpose, I control for a vector of state-level labor force composition for different industry segments. Rajan and Zingales (1998) document that industries, such as manufacturing, which are more dependent on external financing expand faster in developed financial systems. Acharya and

Xu (2017) also find that firms in industries which are more dependent on external financing have better patent portfolio than private firms in the same industry. Therefore, bank liquidity creation is less likely to influence industries which have better access to capital markets.

First, I control for state-level labor force composition following Morgan, et al. (2004) for eight different industry segments: Manufacturing, Construction, Finance, Mining, Service, Government, Trade, and Transportation. Each variable is defined as the fraction of state employment in each industry segment that is from nonfarm state employment. Industry is defined by NAICS from 1997-2006, and SIC from 1984-1996. The results are reported in Panel A of Table 8. In columns 1 and 2 in Panel A of Table 8, I replace state-level control variables used in my baseline model with aggregate state-industry-level variables to avoid overspecification bias.[12] The results in column 1 and 3 suggest that there is a negative association between bank liquidity creation and corporate innovation even after controlling for different US state-level industry segments. Consistent with finding of Acharya and Xu (2017) firms in industries which are more dependent to external finance such as services have higher level of innovation intensity.

Second, bank liquidity creation may positively influence productivity, and economic activities if financing constrains of the firms are alleviated. On the other hand, it may lower the productivity and lead to less growth if it causes defaults and excessive debt burdens. The Strahan (2008) states that the channel of liquidity creation from lines of credit is more important than the asset side. Therefore, in columns 3 and 4 in Panel A of Table 8 I investigate whether bank liquidity creation affects technological productivity though banking credit channel. To investigate this question, I include the ratio of commercial and industrial (C&I) lending to total loans in the regression as a control variable after controlling for state level industry segments.[13] The results in the columns 3 and 4 in Panel A of Table 8 are net of any effect that may come through this channel. Hence, when this channel is excluded from the sets of controls, the impact of bank liquidity creation on technological innovation should be larger. Consistent with this, I find that when the

[12] In an untabulated test, I include all the variables used in my baseline model as well as all state-level industry segments. The results remain unchanged.

[13] Kashyap and Stein (2000) argue that C&I lending might provide more direct impact on real economic activities. Thus, unlike total loans which include residential and household loans, C&I might offer more direct insight into potential impact on productivity. In an unreported test, I also include this ratio in my baseline model. The results remain unchanged.

channel is introduced, the impact of bank liquidity creation on innovation productivity weakens and its significance level drops.

[Table 8]

Finally, I aggregate the innovation output across firms in the same two-digit SIC code industry in each year. Panel B and Panel C of Table 8 only preset the coefficient estimates on liquidity creation using the state-industry-level innovation output as dependent variables. I include labor force composition for eight different industry segments as controls to control for local demand conditions, as well as state and year fixed effects as control variables. The results suggest that the observed negative association between bank liquidity creation and corporate innovation is mainly driven by two industries, namely finance and manufacturing. However, liquidity creation is positively associated with the innovation quality in industries such as service and construction. Lerner, Speen, Baker, Leamon. (2016) argue that patented innovations in finance industry are different and there are deficiencies in financial patenting.

3.2.3. Asymmetry and Non-linearity

A natural question that emerges from observed negative relation between bank liquidity creation and innovation output is whether the linkage between liquidity creation and innovation productivity is non-linear in the form of asymmetry. To capture the asymmetric nature of this relationship, I decompose total liquidity creation measure into positive and negative components. Specially, I define:

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

$$LC_{it}^{-} = LC_{it} - LC_{it-1} if \ (LC_{it} - LC_{it-1}) < 0 \ , otherwise \ 0.$$

where LC_{it} is the change in liquidity creation divided by change in total assets at state *i* from *t* to *t-1*. I then replace total liquidity creation measure by the positive and negative components in the baseline model. This approach allows me to compare the effect of negative and positive shocks of bank liquidity creation on innovation productivity. The panel A of Table 9 reports these results. The results suggest that a positive change in total liquidity creation is negatively associated with innovation output, while a decrease in liquidity creation has a positive but insignificant impact on innovation. This difference is statistically significant suggesting that the effect of bank liquidity creation on innovation output is asymmetric.

[Table 9]

Second, I examine how the effect of bank liquidity creation on innovation output changes over business cycle fluctuations. To investigate this question, I identify the expansion and recession periods using the information provided by the Federal Reserve Bank of St. Louis. Using the annual smoothed US recession probabilities obtained from a dynamic-factor Markov-switching model, the Federal Reserve Bank of St. Louis identifies two recession period from 1984 to 2006.[14] In particular, the first recession occurred in early 1990s (1990-1991), and the second recession hit the US economy in early 2000s (2000-2001).

The theoretical model of Aghion and Saint-Paul (1998) suggests that firms behave differently during economic booms and contractions. Firms tend to invest more in productivity-enhancing projects during recessions, because the opportunity cost of long-term innovative investments instead of short-term working capital investments is lower during economic contractions than economic booms. Also, the theory of "creative destruction" proposed by Schumpeter suggests that recessions could have a positive impact on aggregate productivity, because economic downturns may shift factors of production from less productive to more productive ones.[15] In addition, the recent empirical papers suggest a non-linear relationship in finance-growth nexus, and find that finance becomes detrimental beyond some thresholds (see e.g. Cecchetti and Kharroubi, 2012; Law and Singh, 2014; and Arcand et al., 2015). Hence, I expect that the effect of bank liquidity creation on innovation productivity is non-linear over the business cycle.

Panel B of Table 9 provides insight into the non-linear relation in the form of asymmetry between bank liquidity creation and innovation output during economic contractions and expansions. From Panel B of Table 9, I observe that during economic expansion there is a negative relation between bank liquidity creation and innovation output. However, this relationship is positive but insignificant during economic recessions. Acharya, Shin, and Yorulmazer, (2009) show that risk-shifting incentive encourages banks to hold risky and illiquid assets during boom periods because risky investments are more likely to pay off well during boom periods. Since business cycle fluctuations are related to fluctuations in searching for risky loans by banks, banks may start to fund risky negative NPV innovative projects during economic booms. This would

[14]Chauvet and Piger (2003, 2008) analyze the performance of a parametric Markov-switching dynamic-factor model, and they find that this model accurately identifies the NBER business cycle chronology.
[15] Schumpeter (1934) notes that "[Recessions] are but temporary. They are the means to reconstruct each time the economic system on a more efficient plan."

explain the overall negative relation between liquidity creation and technological innovation during boom periods, and suggest that excessively financing risky innovative project during this period may lead to waste of resources. In addition, the model of Thakor (2005) show that during market booms the supply of credit increases inefficiently which results in over-lending by banks. His findings suggest that during economic booms banks desire for risks increases, and greater liquidity creation may occur off the balance sheet. The negative and significant effect of bank off-balance sheet liquidity creation on innovation during economic expansions suggests the importance of off-balance sheet activities by bank during this period.

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

4. Robustness check

To ensure the robustness of my analyses, I perform a series of alternative estimations and tests. These tests are reported in Table 10.

First, in order to ensure that my results are not driven by the method of allocating bank liquidity creation proportionally according to the deposits held in their different branches in multiple states, I re-estimate the baseline model for only single-state banks. For this purpose, I exclude all banks which operate in multiple states from my sample. From columns 1 and 2 of Table 10, I observe that the results do not differ from earlier findings.

Second, I replace total liquidity creation measure by the change in liquidity creation (ΔLC) divided by total assets ($\frac{\Delta \mathrm{LC}}{TA}$) at state *i* from year *t* to year *t-1*. As can be seen from columns 3 and 4 of Table 10, these results are consistent with the previous findings. In columns 5 and 6, I include lagged Lnpat and Lncite on the right-hand-side of the regression, and I find the results continue to hold.

Next, following Hall et al. (2001), I adjust patent counts, and citations using “fixed-effect” approach instead of “quasi-structural” approach, and then re-estimate my baseline models. For this purpose, the citations are adjusted by scaling each citation count by the average number of citations received by all patents granted in the same technology class and year. Similarly, patent counts are adjusted by dividing each patent by the average number of patents of all firms in the same technology class and year. As can be noted from columns 7 and 8 of Table 10, the results also hold when alternative method is used for correcting the truncation bias in patent and citation dataset.

Further, in columns 9 and 10, I re-estimate the baseline models using the natural logarithm of one plus total number of patents and citations in a state in the following two years.[16] The results show that there is a negative association between bank liquidity creation and corporate innovation.

Finally, I re-estimate the baseline model using the natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+4, and I find my results continue to hold.

[Table 10]

6. Conclusion

Even though previous research has revealed that bank liquidity creation is positively related to economic growth, the relation between bank liquidity creation and innovation which is a main channel through which GDP growth is affected is missing in the literature. This paper is the first study to examine the relation between bank liquidity creation and technological innovation. Using a comprehensive measure of bank output and innovation output, I find that bank liquidity creation is negatively associated with innovation output. The result is consistent with the view that when banks excessively finance innovative projects, the exploration of technological space is excessively performed by firms, leading to waste of resources. I also show that the observed negative relationship is mainly driven by finance and manufacturing industries.

In further analysis, I find that the liquidity created by large banks is positively related to quantity of innovation output but unrelated with quality of innovation. This shows that large banks matter more for the economy. In addition, I find that bank liquidity creation has a positive impact on innovation productivity by firms with more tangible assets. The evidence suggests that although bank liquidity creation adversely affects firms' innovation on average, this effect mainly comes from the group of firms with below-median asset tangibility.

I also find that bank liquidity creation affects innovation output through the bank lending channel. When credit volume channel is introduced in the regression, bank liquidity creation loses some of its power and its impact on innovation productivity becomes smaller. Finally, I analyze whether the relation between bank liquidity creation and innovation output is asymmetric, and I find that the effect of bank liquidity creation on innovation productivity is non-linear in the form of asymmetry.

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

This study has important policy implications. The results suggest that too much provision of liquidity is not always beneficial to the economy. As higher level of liquidity creation is associated with lower innovation productivity, excessive level of liquidity creation may become detrimental to the growth due to excessively financing unsuccessful and unfruitful innovative projects. Even though previous researchers find that bank liquidity creation is one of the determinants of economic growth, if high level of liquidity creation has a negative impact on innovation, then other growth-enhancing strategies need to be implemented in keeping long-run economic benefits. As a result, knowing the efficient and optimal levels of financial resources to productive activities is crucial to ensure the effectiveness of bank liquidity creation for economic growth.

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Table 1

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

Variables	Definition	Sources
Lnpat	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+3. Patent counts are adjusted using the "weight factors" computed from application-grant empirical distribution (quasi-structural approach).	NBER patent database
Lncite	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+3. I use the variable “hjtwt” provided by the NBER database. It is adjusted using "weight factor" computed from citation-lag distribution (quasi-structural approach).	NBER patent database
Lnpat_fixed	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+3. Patent counts are adjusted using fixed effect approach by scaling each patent by the average number of patents of all firms in the same year and technology class (HJT tech category).	NBER patent database
Lncite_fixed	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+3. Citation counts are adjusted using fixed effect approach by dividing each citation counts by the average number of citations received by all patents granted in the same year and technology class (HJT tech category).	NBER patent database
$Lnpat_{t+2}$	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+2. Patent counts are adjusted using the "weight factors" computed from application-grant empirical distribution (quasi-structural approach).	NBER patent database
$Lncite_{t+2}$	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+2. I use the variable “hjtwt” provided by the NBER database. It is adjusted using "weight factor" computed from citation-lag distribution (quasi-structural approach).	NBER patent database
$Lnpat_{t+4}$	Natural logarithm of one plus the state total number of patents filed in years t+1 through t+4. Patent counts are adjusted using the "weight factors" computed from application-grant empirical distribution (quasi-structural approach).	NBER patent database
$Lncite_{t+4}$	Natural logarithm of one plus the state total number of citations received on the firm's patents filed in years t+1 through t+4. I use the variable “hjtwt” provided by the NBER	NBER patent database

	database. It is adjusted using "weight factor" computed from citation-lag distribution (quasi-structural approach).	
Total LC	Total liquidity created by banks in the state normalized by all gross total assets held by banks in the state.	Berger and Bouwman (2009)
LC_OnBS	Total on-balance sheet liquidity created by all banks in the state normalized by all gross total assets held by banks in the state.	Berger and Bouwman (2009)
LC_OffBS	Total off-balance sheet liquidity created by all banks in the state normalized by all gross total assets held by banks in the state.	Berger and Bouwman (2009)
Total_LC_single	Total liquidity created by all banks in the state that only operates in that state normalized by all gross total assets held by banks in the state that only operates in that state	Berger and Bouwman (2009)
Bank equity	Total bank book equity in the state	Call Reports
Rice-Strahan Index (RSI)	Rice-Strahan index of interstate banking deregulation. It ranges from 0 (least restrictive) to 4 (most restrictive).	Rice and Strahan (2010)
US/state Correlation	State economy comovement with the rest of the US, measured as the correlation of the state's coincident index which is estimated based on monthly values of the indexes over 1984-2006.	Federal Reserve Bank of Philadelphia
GDP	The nominal gross product in state *i* in year *t*.	US Bureau of Economic Analysis
PI	Annual percentage change in personal income in the state	US Bureau of Economic Analysis
CI_TA	Ratio of commercial and industrial (C&I) lending to total loans. Total C&I loans by all banks in the state divided by total loans by all banks in the state.	Call Reports
State labor force composition	The labor share of state *i* in year *t* in mining, construction, manufacturing, transportation, trade, service and government. It is defined as the fraction of state employment in each sector in state *i* in year t that is from nonfarm state employment. Industry is defined by NAICS from 1997-2006, and SIC from 1984-1996.	US Bureau of Economic Analysis

CashHoldings	Total cash and marketable securities of the firms in the state to total assets of all firm in the state	Compustat
ROA	Return on assets ratio of all firms in the state. It is defined as operating income before depreciation for all firms in the state divided by total assets of firms in the state	Compustat
LEV	Total leverage ratio of the firms in the state. It is defined as book value of debt for all firms in the state divided by all firms’ total assets in the state	Compustat
CAPEX	Total capital expenditure of all firms in the state scaled by all firms’ total assets in the state	Compustat
LnRD	Natural logarithm of one plus research and development expenditure.	Compustat
TA	All firms' total assets in the state	Compustat

Table 2

Summary statistics. This table contains descriptive statistics (mean, median, standard deviation, first quartile, third quartile, and the number of observations) on all regression variables used in this paper.

Variable	Obs	p25	Median	Mean	p75	Std. Dev.
Lncite	1,000	5.373	7.983	7.300	9.776	3.489
Lnpat	1,000	3.258	5.839	5.292	7.464	2.760
Lncite_fixed	1,000	2.912	5.628	5.064	7.156	2.850
Lnpat_fixed	1,000	3.212	5.620	5.179	7.264	2.730
$Lnpat_{t+2}$	1,050	4.526	7.402	4.892	7.014	2.721
$Lncite_{t+2}$	1,050	4.527	7.402	6.689	9.279	3.590
$Lnpat_{t+4}$	950	3.555	6.111	5.583	7.770	2.782
$Lncite_{t+4}$	950	5.792	8.358	7.739	10.155	3.437
LC_OffBS	1,000	0.073	0.123	0.195	0.189	0.374
LC_OnBS	1,000	0.169	0.224	0.214	0.261	0.069
Total LC	1,000	0.279	0.359	0.410	0.436	0.368
LC+	1,000	0.000	0.018	0.039	0.044	0.099
LC-	1,000	-0.002	0	-0.012	0	0.068
ΔLC	950	-0.003	0.020	0.029	0.045	0.126
Total LC_single	1000	0.248	0.322	0.384	0.392	0.388
Total LC_small	884	0.370	0.434	0.525	0.517	0.472
Total LC_large	884	0.205	0.268	0.292	0.341	0.156
LC_OnBS_small	884	0.209	0.251	0.241	0.283	0.072
LC_OffBS_small	884	0.125	0.182	0.284	0.250	0.493
LC_OnBS_large	884	0.153	0.196	0.204	0.255	0.074
LC_OffBS_large	884	0.043	0.060	0.087	0.081	0.138
cash	1,000	0.031	0.047	0.053	0.066	0.036
GDP	1,000	4.180	5.777	5.996	8.074	3.428
RS	1,000	3	4	3.309	4	1.234
PI	1,000	4.318	5.919	5.992	7.720	2.616
CAPEX	1,000	0.027	0.040	0.046	0.055	0.044
lnRD	1,000	3.268	5.796	5.451	7.744	2.841
ROA	1,000	0.061	0.086	0.082	0.106	0.084
LEV	1,000	0.235	0.287	0.304	0.350	0.117
Correlation	1,000	0.911	0.981	0.819	0.994	0.421
Equity	1,000	0.350	0.560	0.767	0.844	1.025
CI_TL	989	0.140	0.198	0.206	0.265	0.083
CONSTRUCTION	989	4.971	5.649	5.711	6.326	1.005
FINANCE	989	6.467	7.243	7.475	8.297	1.488
GOVERNMENT	989	13.720	15.585	16.297	18.310	3.513
MANUFACTURE	989	9.293	12.918	12.930	16.475	5.269
MINING	989	0.159	0.346	1.000	1.087	1.534
SERVCE	989	25.818	28.478	29.505	32.172	5.448
TRADE	989	20.233	21.744	20.912	22.587	2.707
TRANSPORT	989	4.048	4.744	4.734	5.360	1.006

Table 3

The effect of bank liquidity creation on technological innovation. The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

	Lnpat	Lnpat	Lncite	Lncite
Total LC	-0.258***	-0.212**	-0.354***	-0.309***
	(0.085)	(0.088)	(0.087)	(0.068)
cash		2.185*		1.552
		(1.145)		(1.225)
GDP		0.007		0.025*
		(0.011)		(0.015)
RS		0.079*		0.099*
		(0.044)		(0.054)
PI		-0.019		-0.013
		(0.012)		(0.021)
CAPEX		4.149**		5.548**
		(2.056)		(2.215)
lnRD		0.293**		0.298**
		(0.131)		(0.128)
ROA		2.135*		3.539**
		(1.139)		(1.355)
LEV		-0.608		0.153
		(0.563)		(0.583)
Correlation		0.019		-0.003
		(0.053)		(0.088)
Constant	4.784***	2.756***	7.059***	4.293***
	(0.139)	(0.884)	(0.227)	(0.928)
Observations	1,000	1,000	1,000	1,000
R-squared	0.224	0.350	0.622	0.659
Number of groups	50	50	50	50
Time FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes

Table 4

The effect of on- and off-balance sheet liquidity creation on technological innovation. The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

	Lnpat	Lnpat	Lncite	Lncite
LC_OnBS	-0.259		0.566	
	(1.023)		(1.195)	
LC_OffBS		-0.199**		-0.320***
		(0.083)		(0.075)
cash	2.153*	2.225*	1.702	1.615
	(1.151)	(1.148)	(1.256)	(1.227)
GDP	0.009	0.007	0.027*	0.025*
	(0.011)	(0.011)	(0.014)	(0.015)
RS	0.075*	0.077*	0.082*	0.096*
	(0.043)	(0.044)	(0.047)	(0.054)
PI	-0.022*	-0.019	-0.017	-0.013
	(0.013)	(0.012)	(0.021)	(0.021)
CAPEX	4.245**	4.146**	5.645**	5.532**
	(2.052)	(2.058)	(2.220)	(2.217)
lnRD	0.295**	0.295**	0.308**	0.301**
	(0.131)	(0.132)	(0.129)	(0.128)
ROA	2.187*	2.132*	3.586**	3.528**
	(1.136)	(1.141)	(1.359)	(1.358)
LEV	-0.610	-0.607	0.152	0.155
	(0.571)	(0.561)	(0.588)	(0.579)
Correlation	0.017	0.023	0.010	0.001
	(0.046)	(0.053)	(0.078)	(0.088)
Constant	2.762***	2.713***	4.114***	4.231***
	(0.915)	(0.886)	(0.974)	(0.929)
Observations	1,000	1,000	1,000	1,000
R-squared	0.346	0.350	0.657	0.660
Number of groups	50	50	50	50
Time FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes

Table 5

The effect of bank liquidity creation on innovation output for firms with above-median tangible assets. The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

	Lnpat	Lncite
Total LC	0.233**	0.348
	(0.116)	(0.332)
cash	0.085	-0.603
	(0.891)	(1.078)
GDP	0.018	0.041*
	(0.013)	(0.021)
RS	0.079	0.005
	(0.063)	(0.096)
PI	-0.020	0.009
	(0.017)	(0.029)
CAPEX	4.051*	5.784**
	(2.359)	(2.748)
lnRD	0.229*	0.223*
	(0.130)	(0.127)
ROA	2.249*	3.809**
	(1.228)	(1.508)
LEV	0.054	0.593
	(0.503)	(0.809)
Correlation	-0.045	-0.135
	(0.056)	(0.106)
Constant	2.559**	4.189***
	(0.988)	(1.142)
Observations	1,000	1,000
R-squared	0.212	0.613
Number of groups	50	50
Time FE	Yes	Yes
State FE	Yes	Yes

Table 6

The effect of bank creation on technological innovation by bank size. The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

	Lnpat	Lncite
Total LC_small	-0.215**	-0.191***
	(0.084)	(0.069)
Total LC_large	0.351*	-0.129
	(0.209)	(0.194)
LC_OnBS_small		
LC_OffBS_small		
LC_OnBS_large		
LC_OffBS_large		
cash	0.887	-0.712
	(1.241)	(1.326)
GDP	0.017	0.034**
	(0.011)	(0.016)
RS	0.042	0.063
	(0.040)	(0.049)
PI	-0.009	0.013
	(0.015)	(0.024)
CAPEX	1.708	3.443
	(3.103)	(3.195)
lnRD	0.228*	0.193
	(0.132)	(0.122)
ROA	4.399*	8.462***
	(2.388)	(2.630)
LEV	-0.931	0.328
	(0.886)	(1.039)
Correlation	0.014	-0.025
	(0.053)	(0.079)
Constant	3.278***	7.059***
	(1.116)	(0.227)
Observations	884	884
R-squared	0.393	0.737
Number of groups	50	50
Time FE	Yes	Yes
State FE	Yes	Yes

Table 7

The effect of bank liquidity creation on technological innovation in a 2SLS setting, and the test of reverse causality. Columns 1 and 3 report the first-stage results and columns 2 and 4 show the second-stage results. Equity per capita is used as an instrumental variable. Columns 5 and 6 present the test for reverse causality. In columns 5 and 6, the dependent variable is bank liquidity creation, and the key independent variables are Lnpat and Lncite (both lagged one year). Lagged bank liquidity creation (Total LC_{t-1}) is also included as a control variable, following the methodology of Granger (1969). The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

	Total LC	Lnpat	Lncite	Total LC	Total LC
Equity	0.355***				
	(0.022)				
Total LC		-0.224***	-0.218**		
		(0.070)	(0.094)		
Total LC_{t-1}				0.924***	0.925***
				(0.045)	(0.044)
$Lnpat_{t-1}$				-0.004	
				(0.003)	
$Lncite_{t-1}$					0.002
					(0.003)
cash	0.094	2.183***	1.562*	-0.003	-0.019
	(0.121)	(0.659)	(0.876)	(0.052)	(0.051)
GDP	-0.003	0.007	0.026*	-0.002	-0.002
	(0.003)	(0.010)	(0.014)	(0.004)	(0.004)
RS	0.008*	0.080***	0.096***	0.004**	0.003*
	(0.004)	(0.020)	(0.032)	(0.002)	(0.002)
PI	0.002	-0.019	-0.015	0.009	0.009
	(0.006)	(0.017)	(0.026)	(0.009)	(0.009)
CAPEX	0.205	4.144***	5.585***	-0.090	-0.121
	(0.147)	(0.903)	(1.474)	(0.108)	(0.120)
lnRD	0.019***	0.293***	0.300***	-0.004	-0.006**

	(0.007)	(0.048)	(0.067)	(0.002)	(0.003)
ROA	0.112	2.132***	3.558***	0.000	-0.017
	(0.069)	(0.465)	(0.799)	(0.032)	(0.038)
LEV	0.058	-0.608**	0.153	0.026	0.027
	(0.063)	(0.268)	(0.421)	(0.017)	(0.018)
Correlation	-0.015	0.019	-0.002	0.002	0.002
	(0.013)	(0.047)	(0.070)	(0.006)	(0.006)
Constant	-0.055	-1.067***	-1.452***	0.008	-0.010
	(0.061)	(0.277)	(0.482)	(0.032)	(0.039)
Observations	1000	1,000	1000	1,000	1,000
R-squared	0.868	0.960	0.946	0.879	0.879
Number of groups	50	50	50	50	50
Time FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes

Table 8

The effect of bank liquidity creation on technological innovation using state-industry level variable, credit volume channel, and state-industry-level innovation output. The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A				
	Lnpat	Lncite	Lnpat	Lncite
Total LC	-0.391***	-0.308***	-0.327**	-0.252**
	(0.145)	(0.110)	(0.127)	(0.118)
CONSTRUCTION	0.441**	0.775***	0.435**	0.769***
	(0.216)	(0.244)	(0.197)	(0.234)
FINANCE	0.218	0.193	0.169	0.149
	(0.168)	(0.214)	(0.161)	(0.218)
GOVERNMENT	0.197	0.445*	0.155	0.408*
	(0.197)	(0.235)	(0.175)	(0.223)
MANUFACTURE	0.225	0.473**	0.211	0.461**
	(0.145)	(0.185)	(0.134)	(0.184)
MINING	0.404**	0.634***	0.348**	0.584**
	(0.170)	(0.232)	(0.146)	(0.224)
SERVCE	0.175	0.461**	0.159	0.447**
	(0.141)	(0.204)	(0.126)	(0.199)
TRADE	0.315	0.661**	0.251	0.603**
	(0.219)	(0.269)	(0.195)	(0.259)
TRANSPORT	0.161	0.142	0.167	0.148
	(0.192)	(0.210)	(0.187)	(0.211)
CI_TL			-3.501**	-3.113**
			(1.407)	(1.340)
NPLs_TL				
Constant	Yes	Yes	Yes	Yes

Observations	989	989	989	989
R-squared	0.287	0.658	0.319	0.666
Number of groups	50	50	50	50
Time FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes

Panel B

The number of citations across all firms in each industry	Coefficient on Total LC	t-stats
Mining	-0.083	-0.43
Agriculture, Forestry and Fishing	0.097	0.59
Construction	0.256*	1.90
Manufacturing	-0.222*	-1.96
Transportation, Communications, Electric, Gas and Sanitary service	0.385	1.04
Wholesale Trade	0.186	0.71
Retail Trade	-0.048	-0.21
Finance, Insurance and Real Estate	-0.628*	-1.96
Services	0.709***	3.45
Other	0.333	1.47

Panel C

The number of patents across all firms in each industry	Coefficient on Total LC	t-stats
Mining	-0.019	-0.19
Agriculture, Forestry and Fishing	0.060	0.70
Construction	0.086	1.44
Manufacturing	-0.277**	-2.31
Transportation, Communications, Electric, Gas and Sanitary service	0.022	0.10
Wholesale Trade	-0.004	-0.03
Retail Trade	0.013	0.11
Finance, Insurance and Real Estate	-0.513**	-2.45

Services	-0.485**	-2.10
Other	0.112	0.95

Table 9

The effect of positive and negative LC shocks on technological innovation, and its effect over the business cycle phases. Using the annual smoothed US recession probabilities obtained from a dynamic-factor Markov-switching model, the Federal Reserve Bank of St. Louis identifies two recession period from 1984 to 2006. The first recession hit the US economy during 1990-1991, and the second one occurred in 2000-2001. T-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

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

	Lnpat	Lncite
LC_{+}	-0.018***	-0.009*
	(0.007)	(0.005)
LC_{-}	0.003	0.002
	(0.003)	(0.003)
Controls	Yes	Yes
Constant	Yes	Yes
Time FE	Yes	Yes
State FE	Yes	Yes

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

	Economic Expansions						Economic Contractions					
	Lnpat	Lnpat	Lnpat	Lncite	Lncite	Lncite	Lnpat	Lnpat	Lnpat	Lncite	Lncite	Lncite
Total LC	-0.222**			-0.333***			0.051			0.071		
	(0.098)			(0.061)			(0.162)			(0.221)		
LC_OnBS		0.045			0.722			-1.432			-0.332	
		(1.068)			(1.173)			(1.726)			(2.027)	
LC_OffBS			-0.220**			-0.348***			0.100			0.075
			(0.099)			(0.074)			(0.186)			(0.252)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 10

Robustness check. The sample period is 1984-2006, and t-statistics based on standard errors clustered at the state level are in parentheses. All variables are defined as in Table 1. *, **, ** denote significance at the 10%, 5%, and 1% levels, respectively.

	Lnpat	Lncite	Lnpat	Lncite	Lnpat	Lncite	Lnpat_fixed	Lncite_fixed	$Lnpat_{t+2}$	$Lncite_{t+2}$	$Lnpat_{t+4}$	$Lncite_{t+4}$
Total LC							-0.177***	-0.210***	-0.235*	-0.299***	-0.143**	-0.286***
							(0.058)	(0.059)	(0.122)	(0.097)	(0.059)	(0.069)
Total LC_single	-0.176**	-0.265***										
	(0.086)	(0.063)										
ΔLC/TA			-0.296***	-0.380**	-0.229***	-0.339***						
			(0.095)	(0.163)	(0.042)	(0.069)						
$Lnpat_{t-1}$					0.883***							
					(0.036)							
$Lncite_{t-1}$						0.749***						
						(0.071)						
cash	2.191*	1.561	2.361*	2.013	-0.001	-0.309	1.740*	1.867*	2.239*	1.281	2.111*	1.565
	(1.145)	(1.226)	(1.252)	(1.417)	(0.331)	(0.566)	(1.022)	(1.017)	(1.128)	(1.276)	(1.121)	(1.265)
GDP	0.007	0.025*	0.004	0.018	0.000	0.013*	0.015	0.016	0.006	0.045**	0.006	0.016
	(0.011)	(0.015)	(0.009)	(0.012)	(0.004)	(0.007)	(0.011)	(0.011)	(0.010)	(0.020)	(0.012)	(0.013)
RS	0.080*	0.100*	0.073	0.090	0.002	-0.001	0.077*	0.073	0.068	0.073	0.063	0.105**
	(0.044)	(0.054)	(0.044)	(0.055)	(0.013)	(0.025)	(0.043)	(0.044)	(0.041)	(0.066)	(0.042)	(0.050)
PI	-0.019	-0.014	-0.024**	-0.022	-0.011*	-0.010	-0.010	-0.002	-0.009	-0.030	-0.018	-0.024
	(0.012)	(0.021)	(0.011)	(0.017)	(0.006)	(0.014)	(0.012)	(0.015)	(0.013)	(0.025)	(0.013)	(0.020)
CAPEX	4.151**	5.548**	4.407**	5.978***	0.578	1.005	3.828*	4.845***	4.090*	5.459*	4.128**	5.867**
	(2.050)	(2.210)	(2.039)	(2.219)	(0.614)	(1.030)	(2.016)	(1.800)	(2.206)	(2.731)	(2.000)	(2.492)
lnRD	0.294**	0.301**	0.252**	0.229**	-0.035	-0.042	0.283**	0.290***	0.328**	0.298**	0.301**	0.277**
	(0.131)	(0.127)	(0.125)	(0.111)	(0.037)	(0.046)	(0.115)	(0.102)	(0.123)	(0.131)	(0.132)	(0.136)
ROA	2.137*	3.541**	2.241*	3.713***	0.264	0.814	2.135*	2.689**	2.122*	3.707**	2.107*	3.460**

	(1.134)	(1.350)	(1.121)	(1.353)	(0.321)	(0.584)	(1.123)	(1.009)	(1.169)	(1.536)	(1.133)	(1.472)
LEV	-0.608	0.154	-0.621	0.241	-0.229	0.166	-0.333	-0.118	-0.486	0.446	-0.681	-0.066
	(0.563)	(0.583)	(0.622)	(0.619)	(0.214)	(0.293)	(0.493)	(0.391)	(0.502)	(0.692)	(0.601)	(0.585)
Correlation	0.020	-0.003	0.027	0.015	0.063**	0.025	-0.013	-0.018	-0.074	-0.086	0.018	0.000
	(0.053)	(0.088)	(0.054)	(0.088)	(0.025)	(0.049)	(0.053)	(0.056)	(0.048)	(0.092)	(0.057)	(0.093)
Constant	2.734***	4.262***	3.052***	4.973***	0.854***	2.047***	2.620***	2.299***	2.251**	3.915***	3.149***	5.124***
	(0.884)	(0.928)	(0.788)	(0.657)	(0.264)	(0.521)	(0.823)	(0.792)	(0.900)	(1.103)	(0.790)	(0.708)
Observations	1,000	1,000	950	950	950	950	1,000	1,000	1,050	1,050	950	950
R-squared	0.350	0.659	0.336	0.695	0.844	0.865	0.494	0.489	0.349	0.698	0.362	0.605
Number of groups	50	50	50	50	50	50	50	50	50	50	50	50
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Appendix 1.

Table A.1. Construction of liquidity creation measure.

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