Investing in Lending Technology: IT Spending in Banking*

Zhiguo He, Sheila Jiang, Douglas Xu, Xiao Yin

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Abstract

This paper investigates lending technologies in the banking sector after the arrival of the information age, by examining investment in information technologies (IT) by U.S. commercial banks. Given the distinctive nature of banks' dealings with information as they engage in lending activities, we link banks' IT spending in various categories to different aspects of their lending technologies. Investment in communication IT is shown to be associated more with improving banks' ability of soft information production and transmission, while investment in software IT helps enhance banks' hard information processing capacity. By exploiting polices that affect geographic regions differentially, we show that banks respond to an increased demand for small business credit (mortgage refinance) by increasing their spending on communication (software) IT spending. We also find an asymmetric impact of technological development on labor employment in the banking sector.

Keywords: Information Technology, Small Business Lending, Mortgage Refinance, Communication Equipment, Software, Hard and Soft Information

JEL codes: G21, G51, J24, O32

*He: Booth School of Business, University of Chicago and NBER, zhiguo.he@chicagobooth.edu; Jiang: Warrington College of Business, University of Florida, sheila.jiang@warrington.ufl.edu; Xu: Warrington College of Business, University of Florida, douglas.xu@warrigton.ufl.edu; Yin: PhD program in Finance, Haas School of Business, University of California, Berkeley, yinxiao@berkeley.edu. We are thankful for valuable comments from seminar participants at the Richmond Fed, University of Connecticut and University of Florida. Zhiguo He acknowledges financial support from the John E. Jeuck Endowment at the University of Chicago Booth School of Business. All errors are our own.

1 Introduction

Commercial banks have long relied on cutting-edge technology to deliver innovative products such as ATMs and online banking, streamline loan making processes, and improve back-office efficiency. According to a 2012 Mckinsey Report, across the globe commercial banks spend about 4.7% to 9.4% of their operating income on information technology (IT); for comparison, insurance companies and airlines only spend 3.3 percent and 2.6 percent of their income, respectively. This trend has accelerated at an unprecedented pace in recent years, especially after the COVID-19 pandemic, as industry professionals often consider top commercial banks to be more like "technology companies" than actual technology companies by virtue of their enormous IT budgets.[1] Recently, the impact of information technology on the banking sector and financial stability has been a hot topic in policy discussions (Banna and Alam (2021), Pierri and Timmer (2020)).

Although the financial services industry—especially the banking industry—is increasingly becoming a tech-like business, the academic literature lags behind in understanding the economics of IT spending in the banking industry. Which banks, large or small, have invested more? How does IT spending affect banks' lending technology and loan making? Our study takes the first step toward understanding the basic pattern of these banking IT expenditures and explores the connections and underlying mechanisms between these expenditures and the core functioning of the banking system.

To place our research in the established banking literature, think about the information transmission between a loan officer and a borrower, or across layers of loan officers within a bank organization. As highlighted by Stein (2002), soft information tends to be more effectively transmitted and thus lending decisions are more easily determined when a bank

[1] For instance, this article shows that IT spending by most top banks, including JP Morgan, Bank of America, Citi, Goldman Sachs and international leaders like Deutsche Bank and Barclays, exceeds 17% of their total operating costs, while Amazon and Alphabet devote 12% and 20% of their operating costs respectively to IT. This article stresses that banks are still lagging quite a bit in their IT spending in absolute terms, and cautions further that the above-mentioned IT spending numbers do not include compensation for IT staff members.

has less hierarchical structure. The fast developing technologies in recent decades provide more options for the banking sector to cope with such problems. Indeed, in recent years banks have been observed to pay more attention to strengthening their internal communication through the wide use of private branch exchanges and intranet installment.[2] And technology advances extend far beyond internal communication; for instance, the explosive big data analytics market—which combines "hard" information like credit scores and other alternative data—calls for automatic information processing as a pressing need for banks today.

Our study relies on a comprehensive dataset, the Harte Hanks Market Intelligence Computer Intelligence Technology database, which has been used in the economics literature (e.g., Bloom et al. (2014) and Forman et al. (2012)) for studying the economic implications of technology adoption in the non-financial sector. Focusing on commercial banks, we are the first—to the best of our knowledge—to analyze this dataset with detailed branch-level information on detailed spending categories.

Section 2.2 explains in detail the four major categories of IT expenditure in the Harte Hanks dataset—hardware, software, communication, services—in the context of the banking industry. As we will explain shortly, our study focuses on two of these four categories. First, *Software* includes desktop applications (e.g., Microsoft Office), information management software, and risk and payment management software. By greatly improving the efficiency of document assembly, digitization, information classification, these software products automate information processing through specialized programming and AI technologies and thus improve both accuracy and processing speed.

On the other hand, *Communication*, which includes radio and TV transmitters, private branch exchanges, and video conferencing, is defined as the network equipment that banks operate to support their communication needs. For instance, a set of advanced communication equipment allow bankers to interact with their borrowers in a more effective way; and private branch exchanges facilitate smoother exchanges of information and opinions within

[2]For instance, a news article on Finextra reports the installment of intranet by First Citizens National Banks.

the bank branching network.

In Section 3, we start our analysis by first documenting that IT expenditure in the US banking sector has been growing rapidly over the last decade; for instance, average IT spending as a share of total expenses has grown from nearly nil in 2010 to around 5% since 2015. A further examination across bank size groups reveals a somewhat different pattern between small and large banks in terms of their time trends as well as the structure of IT spending. The IT spending at large banks (asset size $10–250 billion) has been steadily growing, while there is almost no growth in the smallest group (asset size below $0.1 billion). Interestingly, medium-sized banks saw the fastest growth in their IT spending during 2010–2014 but dramatically slowed down during 2015–2019; while mega banks (asset size above $250 billion) only picked up their IT spending after 2015. In terms of the IT spending profile, a noticeable distinction is that smaller banks consistently allocate a higher share of their IT budget towards communication technology than larger banks do.

As we aim to achieve a better understanding of the formation of banks' lending technology during the information age, a natural yet important step is to examine the relationship between banks' investment in IT and their lending activities. Section 3.3 documents how banks' loan categories on balance sheets vary with their IT spending profiles. Among the three large loan types in Call Report, we find that the shares in commercial and industrial (C&I) loans and agricultural loans are positively associated with their communication spending, but uncorrelated with software spending, whereas the share of personal loans appears to be positively associated with banks' software spending, but not with communication spending. Furthermore, within C&I loans, small business lending stands out to drive the positive association with communication IT spending; whereas within the personal loans, mortgage refinance drives the positive association between personal loans and software spending. These findings are robust at both bank and bank-county-year level.

Based on the above findings, we develop three main hypotheses in Section 4 linking the nature of information in banks' lending activities to their IT spending behaviors. Conceptually, we differentiate two fundamental types of bank lending technologies. The first heavily relies on the gathering and augmentation of soft information from borrowers; in the context of Berger and Udell (2002a), "relationship lending" is a concrete example of the first type. The second fundamental type of lending technology, on the other hand, relies primarily on the processing and quantification of hard information. "Transactions lending" in Berger and Udell (2006), i.e., loans that are based on a specific credit scoring system and quantified financial statement metrics, are standard examples of the second type.

For our first testable hypothesis, we posit that a demand shock of small business credit will lead banks to invest more in communication technologies. This is because communication technologies—say video conferencing—not only enable banks to more effectively collect soft information from small business borrowers (who often inhabit an opaque information environment), but also allow for a smoother transmission of this otherwise hard-to-verify soft information within a bank organization. Taking advantage of an arguably exogenous demand shifter, we find that an increase in banks' small business credit demand—due to a higher ex-ante exposure of local counties to the policy shock exploited in our analysis—leads to a positive and significant growth in banks' communication spending, without much impact on the bank's software spending.[3]

The second testable hypothesis is that a positive demand shock for mortgage refinancing should push banks to engage in more IT spending on software because software is particularly useful for dealing with existing or readily accessible "hard" information (e.g., credit scoring software utilized by banks when making refinancing decisions). To identify the causal relationship between a demand for "hard" information processing and banks' software spending, we construct a shifter to the mortgage refinance demand faced by banks across different regions. Specifically, we utilize the cross-county variation in the interest payment gap of outstanding mortgages due to the presence of a local mortgage rate gap—a higher interest

[3]We construct our instrumental variable for the shock of small business credit demand based on "Small Business Health care Tax Credit." As a part of the Affordable Care Act, this program was enacted between 2014 and 2015 and provided beneficial tax treatment specifically targeted at small business establishments in the US economy.

payment gap naturally implies a higher mortgage refinance demand by local households. Thanks to this instrumental variable, which has been used in the literature (e.g., Eichenbaum et al. (2018)), we show that a one standard deviation increase in mortgage refinancing lent out by a bank leads to around 5% higher on average software spending intensity relative to the sample average (due to its local exposure to high refinance savings), without any significant impact on local banks' communication spending.

Our last testable hypothesis concerns how investment in IT affects labor in the banking industry, as development in information technologies offers more options for banks to perform "tasks" traditionally undertaken by employing human labor (Acemoglu and Restrepo (2018)). Specifically, utilizing the county-level availability of land-grant colleges as an instrumental variable for local supply of IT-related employees, we find that banks operating in counties with a more abundant supply of IT-related employees have significantly slower software spending growth compare to those located in regions where the supply of IT-related employees is relatively scarce. In contrast, we do not see such a difference in banks' communication spending growth. Quantitatively, a one standard deviation increase in IT-employee hiring growth results in an average of 5.13% slower growth in software spending as a share of branch-level gross revenue. These results, which could be driven by a local wage channel, indicate an important yet asymmetric impact of the development in information technologies on the labor employment outcomes in the traditional banking sector.

Related Literature

Bank lending technology and the nature of information This paper is closely related to the literature of relationship and transactions lending. Berger and Udell (2006) provide a comprehensive framework of the two fundamental types of bank lending technology in the SME lending market.[4] A fundamental difference between these two types of lending is related to the role played by information as highlighted by Stein (2002), who provides

[4]Bolton et al. (2016) study the joint determination of relationship lending and transactions lending. They find that firms that rely more on relationship banking are better able to weather a crisis than firms that rely on transactions banking, suggesting a higher capital requirement for relationship banks.

an explanation as to why soft information production favors an organizational structure with fewer hierarchical layers and why banks cut their lending to small businesses after consolidation. This notion that credible communication is essential for the production of soft information is in line with our finding that spending on communication technology facilitates the generation and transmission of soft information, while smaller banks tend to allocate a higher proportion of their IT budget to communication compared with larger banks.[5]

We contribute to this strand of the literature by linking information technology to bank lending technology, especially on the distinction between soft information production/transmission and hard information processing. We demonstrate causal linkages between the different informational components in credit demand to banks' endogenous decisions on lending technology adoption.[6] Although previous literature has shown how the credit supply will positively affect non-financial firms' technology adoption or innovation (Amore et al. (2013), Chava et al. (2013), Bircan and De Haas (2019)), it remains unknown how credit demand associated of different informational natures will induce the banking sector to upgrade their lending technologies. Establishing such causal relationship could help explain why unbalanced development across different types of information technology could tilt banks' lending towards or away from certain types of lending in the long run.

Information technology and the banking industry While the exact mechanism through which information technology affects banks' lending technology remains somewhat a black box, the interactions between the development of information technology and the evolution of the banking industry have been well explored in the literature. For instance, Hannan and

[5]Along these lines, Liberti and Mian (2009) find empirically that greater hierarchical distance leads to less reliance on subjective information and more on objective information and that more frequent communication between information collecting agents and loan approving officers can mitigate the effects of hierarchical distance on information use. Paravisini and Schoar (2016) document that credit scores, which serve as "hard information," improve the productivity of credit committees, reduce managerial involvement in the loan approval process, and increase the profitability of lending.

[6]Hard and soft information components are never black and white. Berger and Black (2011) emphasize that hard lending technologies often have both hard and soft information components, so large banks' comparative advantage in hard lending technology is dependent on the relative importance of the hard versus soft information components involved in the technology.

McDowell (1984) document that larger banks and banks in a more concentrated banking industry are more likely to adopt automated teller machines. Stepping back into the twentieth century, Berger (2003) shows that technological progress in both information technology and financial technology led to significant improvement in banking services productivity and quality. Petersen and Rajan (2002) document that development in communication technology greatly increased the lending distance of small business loans, reflected in a relaxation in the requirement that firms receiving credit in more distant areas need to have higher credit score.[7]

The emergence of fintech is a signature result of recent developments in information technologies.[8] Our study aligns more closely with the angle addressing how the emergence of fintech industry is affecting (or has affected) the traditional banking sector.[9] While a common theme of this research has mostly focused on examining how the emergent fintech industry is affecting bank-fintech competition, in a process where traditional banks are largely viewed as a *passive* player, and little attention has been paid to how banks are *actively* responding to the emergence of this group of new challengers. Our paper makes the initial step in studying whether and how the traditional banking sector is catching up with the penetrating fintech industry through examining IT investment behavior in the U.S. banking sector.

Endogenous technology adoption and its real impact Recently, there has been a large literature studying the endogenous adoption of IT across non-financial firms or geographical units and its impact on real economic outcomes, such as firm productivity, em-

[7]There is also a vast theoretical literature on the interactions among information technology, banking market competition and bank lending; see Freixas and Rochet (2008) for a review. Hauswald and Marquez (2003) analyzes how two dimensions of technological progress affect competition in financial services. They show that although technological progress will lower the cost of information processing, it also implies lower entry cost and higher competition. So the overall effect of technological progress on interest rates is mixed. More recently, Vives and Ye (2021) study how the diffusion of information technology affects competition in the bank lending market and banking sector stability.

[8]Related works include but are not limited to Di Maggio and Yao (2020), Frost et al. (2019), Hughes et al. (2019), Stulz (2019), Fuster et al. (2019), Buchak et al. (2018), Jagtiani and Lemieux (2017), and Philippon (2020).

[9]Related research in this strand of literature includes Lorente et al. (2018), Hornuf et al. (2018), Calebe de Roure and Thakor (2019), Tang (2019), Erel and Liebersohn (2020), Aiello et al. (2020), Schnabl and Gopal (2020), and He et al. (2021).

ployment and local wages. This literature include McElheran and Forman (2019), Bloom and Pierri (2018), Brynjolfsson and Hitt (2018), Akerman et al. (2015), Bloom et al. (2012), Beaudry et al. (2010), Autor et al. (2003), Brynjolfsson and Hitt (2003).

In particular, to the best of our knowledge, our paper is the first to document that as information technology develops, banks with lower (higher) availability of IT-related employees will accordingly invest more (less) in technology aimed at processing hard information processing, without much impact on investment in communication technology, which primarily helps soft information generation/transmission. These findings suggest that developments in information technology could have an important yet *asymmetric* impact on labor employment in the banking sector.

2 Data and Background

We explain our main data sources in this section, together with detailed explanations of various categories of IT spending.

2.1 Data Source and Sample

The data on banks' IT spending comes from the Harte Hanks Market Intelligence Computer Intelligence Technology database, which includes information on over three million establishment-level IT transactions from 2010 to 2019 from conducting IT-related consulting for firms.[10] Harte Hanks collects and sells this information to technology companies, who then use this information for marketing purposes or to better serve their clients. Firms with IT spending information have incentives to report truthfully to Harte Hanks because they also want to receive advice for better IT services in the future. This data set has been

[10]One data issue is on how to allocate IT costs among branches the headquarter makes the purchase. According to the data provider, in the case where the IT spending made by the headquarters of a bank is distributed to branches, such spending is reflected in the branch's spending rather than in that of the headquarters. Furthermore, by comparing the headquarters and branch spending scaled by revenue of the largest 100 banks in our sample, we find no statistically significant difference between the IT spending intensity at the headquarters and branches.

used in academic research in economics; leading examples include Bloom et al. (2014), who study the impact of information communication technology on firms' internal control, and Forman et al. (2012), who study firms' IT adoption and regional wage inequality.

Our paper focuses on commercial banks; to the best of our knowledge, we are the first to analyze this data set with branch-level information as well as detailed IT spending categories in the context of the banking industry. The sample consists of 1806 commercial banks in the U.S. As shown in Figure A1, which displays the comparison between the total asset size of banks in our sample and that of the overall banking industry in U.S. from 2010 to 2019, our sample covers more than 80% of the U.S. banking sector in terms of asset size.

Our sample is more representative for large banks, as shown in Table 1 which reports the coverage of our sample by bank asset size group. For three groups of banks with asset size above $1 billion, the coverage in frequency and asset are both over 80%. However, for small banks with size less than $100 million, our sample covers 14.45% (14.23%) of the total number (assets) of commercial banks in the U.S. system.

Table 2 displays the summary statistics of banks' IT spending. In our sample, the bank's total IT spending as a percentage of its net income ranges from 1.8% (25th percentile) to 13.5% (75th percentile), suggesting a large variation across different banks. Median IT spending as a share of net income is 5.1% (the 5.1% is calculated by using the observations with positive net income), consistent with the 2012 survey by McKinsey reporting that banks' IT spending as a share of net operating income ranges from 4.7% to 9.4%.[11]

2.2 IT Investment Categorization

A major strength of our dataset is that it gives us a detailed decomposition of banks' IT investments in four major categories specified by Harte Hanks: *hardware*, *software*, *communication*, and *services*. We now provide detailed explanations for these categories, with formal definitions given in 5(a) to 5(d) of Figure A4.

[11] A screenshot of the report is in Appendix Figure A3.

Software is defined as software purchased from third parties. This could be packaged or semi-packaged software delivered on CD and installed by the company, or offered on an SaaS from a multitenant shared-license server accessible by a browser, or custom-created for a company by third-party contractors or consultants. More specifically, the category of software includes desktop applications, information management software, processing software, ePurchase, risk and payment management software.

One representative example of desktop application is the Microsoft Office software package; these software products are easy to grasp by bank employees and allow employees to conduct basic calculations and visualization of data that's associated with lending business.[12]

Examples of processing software include Trapeze Mortgage Analytics, Treeno Software, Kofax, eFileCabinet. The specialty of these software products lies in automatically processing information from loan applicants' paper document packets through specialized programming and AI technologies, which greatly improve the efficiency in document assembly, digitization, and information classification, which would otherwise be done manually by loan officers. These software improve accuracy and shorten processing speed.

ePurchase software products allow banks' customers to make fund transfers more easily online and through mobile apps. Examples of ePurchase include Zelle and Stripe. For instance, large banks (say BOA, CitiBank, and Wells Fargo) as well as smaller regional banks (say First Tennessee Bank and SunTrust Bank) have joined the Zelle network, which allows their customers to transfer funds across their bank accounts within seconds.

Risk management software provides on-going risk assessment after loans have been issued, through augmenting borrowers' repayment information as well as real-time industrial and economic conditions. These software products, e.g. Actico, ZenGRC, Equifax, Oracle ERP, allow banks to better monitor loans in progress. Other software products include security trading systems and operating systems that are typically bundled with the specific software products.

[12] For example, on Mendeley.com, the job postings for loan officers or project managers by many banks require applicants to be proficient with Microsoft Office.

Communication is defined as the network equipment that banks operate to support their communication needs. It includes routers, switches, private branch exchanges, radio and TV transmitters, Wi-Fi transmitters, desktop telephone sets, wide-area networks, local-area network equipment, video conferencing systems, and mobile phone devices.

When there is a need for bankers to contact or interact directly with borrowers, a set of advanced communication equipment allows bankers to more effectively talk to and see borrowers. In addition, communication equipment such as private branch exchanges allow the exchange of information, opinions, and decisions more effectively done within the bank branching network.

Hardware as a form of IT investment includes classic computer hardware such as PCs, monitors, printers, keyboard, USB devices, storage devices, servers, and mainframes. In terms of lending services, hardware is a fundamental type of tech investment that complements and facilitates both the gathering of borrower information and the processing of that information. This is because hardware devices, such as PCs and servers, help provide storage and transmission of data, and meanwhile they serve as the carriers of software and toolboxes (that are needed to process, calculate and analyze the data). Computers are also important in the context of services on transaction accounts: with computers, bank tellers can quickly locate depositors' data by typing in their names, as opposed to manually finding that depositor's file folder.

Services are defined as project-based consulting services or systems integration services that vendors provide to banks. Specifically, these include consulting services for IT strategy, security assessments, system integration, project services, hardware support and maintenance services. The services are mainly provided by IT outsourcing companies on contractual basis. Similar to hardware, services work as complements to other categories of information technology investment to facilitate banks' lending, although these services are not directly associated with banks' information gathering or processing. Examples include Aquiety, a Chicago-based IT service company that provides cybersecurity services to banks and other firms; and Iconic IT, a New-York based IT service company that provides software and hardware procurement, and installment and upgrade services.

2.3 Other Datasets

To supplement our study on banks' lending technologies and banks' IT investments, we combine loan level information from multiple sources.

Bank Balance Sheet We obtain bank-level balance sheet information from Call Report.[13] Total revenue of a branch is from Harte Hanks. Control variables constructed from Call Report include Net income, Equity, and Deposits, all as a ratio of Assets. For bank-county or bank-county-year analysis, we utilize information on banks' revenues at the county level from Harte Hanks. To guarantee the accuracy of this measure, we require that a bank's total revenue not be missing in that county and that the total number of employees at a bank's branches in this county is not missing in the Harte Hanks database when it was surveyed. To construct the key left-hand side variables "IT spending/Revenue," we aggregate all branches' spending in a specific category of bank i in county c in year t, and scale it by the aggregated revenue of all branches of that bank in that county. The control variable "Revenue per employee" is at bank-county-year level, with total revenue and total number of employees both from Harte Hanks. When using this control variable for bank-level analysis, we aggregate revenue and employees at the bank level across the nation and calculate this ratio.

Loans and Local Characteristics We obtain syndicated loan information on the frequency of a bank acting as lead bank in syndicated loan packages from LPC Dealscan. Small business loan origination data are from the Community Reinvestment Act (CRA), which is at the bank-county-year level covering the sample period of 2010–2019. Mortgage refinance information is available in Home Mortgage Disclosure Act (HMDA) from 2010–2019. When

[13] To merge Call Report data with the Harte Hanks data, we merge by bank name using levenshtein distance (similar to the method used in Lerner et al. (2021)) after dropping suffixes such as corporation or inc. And we require a matching score above 90%.

constructing an instrumental variable that serves as a demand shifter, we download the average mortgage interest rate at the county level before 2010 from Freddie Mac. County-level variables are matched by FIPS.

3 Empirical Patterns of Banks' IT Spending

We start our analysis by reporting some basic statistics of banks' investment in IT over the last decade in the U.S. economy and explore how a bank's IT investment relates to its size. We then show that banks' IT investments are closely related to their lending activities, by examining how the profiles of banks' IT investments vary when banks have different specialization in loan types (e.g., commercial loans versus personal loans).

3.1 Time Trends of Banks' IT Investment

Figure 1 displays the average IT spending as a share of total expenses as well as total revenue from 2010 to 2019. Overall, banks have drastically increased their investment in information technologies over the last decade. As a share of total expenses, their IT budgets increased from nearly zero in 2010 to about 5% after 2015. To put these numbers in context, total IT spending across all banks in our sample is about 40% of their total interest expenses in 2016.

After a slight slowdown in 2015, there is a dramatic pick-up of bank IT spending in 2016 as shown in Figure 1. This could be potentially driven by the release of a "white paper" by the Office of the Comptroller of the Currency (the "OCC," the regulator of federally chartered national banks and savings associations) on March 16, 2016, that set forth the OCC's perspective on supporting responsible innovation in the federal banking system. The white paper encouraged banks of all sizes to integrate responsible innovation into their strategic planning and encouraged banks to collaborate with non-banks in developing responsible innovative products that satisfy regulator requirements. As argued by this article, banks might have gained more freedom thanks to this white paper and have been more actively investing in information technology in order to better catch up with fintech development.[14]

Indeed, through examining how this time trend of banks' IT investments moves together with the fintech presence in a local economy, we find evidence suggesting a potential "catching-up" behavior of the traditional banking sector. Figure 2 plots the average IT spending over years as a share of revenue by local commercial banks, for geographic regions featuring high and low fintech presence respectively.[15] While IT spending by banks in both groups share a common upward trend, the group with high fintech presence increases their IT spending at a faster rate than the one with low fintech presence.

As another important input in banks' lending technology investment, banks' IT-related labor hiring—which used to be the major form of lending technology investment before the information age—is also of interest to our study. Figure 3 compares IT spending between banks with high and low levels of IT-related labor employment.[16] We find that banks with low IT-related labor employment have experienced faster growth in IT spending over the last decade, an interesting observation that we come back to in Section 4.4.

In addition to the time dynamics of the IT spending of U.S. commercial banks, another equally important dimension of our analysis is the structure of these investments in information technology. Table 2 reports summary statistics on the detailed structure of banks' IT spending profiles. In particular, we report how banks' investments in IT are distributed across different categories as defined in Section 2.2. By size, software and services are the largest among all categories of IT spending, each constituting 33% of total IT budget. Hardware constitutes about 17% of total IT budget, and communication is on average 9%. In our sample, an average bank has a storage size of 3.52PB (3604.5 TB) and 133 IT-related

[14]This article by McKinsey documents a fintech IPO boom as well as a fintech investment boom by venture capitalists since 2016.

[15]County-level fintech presence measure is based on "Fintech lending share in local mortgage market" proposed in Fuster et al. (2019), and we define high (low) fintech presence regions to be counties with above-median (below-median) of the fintech lending share.

[16]In this comparison, banks with high and low level of IT-related labor employment are defined as banks whose IT employee share (as a fraction of total employee) is above the 80th percentile and below the 20th percentile, respectively.

employees.

3.2 Bank IT Spending across Bank Size

We now examine how IT spending varies across different bank groups, by conducting the same set of analyses as in the last section, but for different banks size groups. Table 2 reports the summary statistics of banks' IT spending and Table A2 reports the summary statistics by bank size. Overall, we find that larger banks tend to make more IT investment as a share of noninterest expenses than smaller banks do. As can be seen in Table A2, banks with total assets of less than $0.1 billion have an average IT/revenue ratio of 1.5%, whereas banks with asset size in the range of $1–$10 billion and banks in the range of $10–$250 billion have an average IT/revenue ratio of 4.3% and 4.5% respectively.

Panel A of Figure 4 displays the time trend of banks' IT investments by each bank size group. Overall, an upward trend in IT spending as a share of total non-interest expense is observed in all bank size groups.[17] Despite this common upward trend over the past decade, there are also some noticeable differences in the detailed dynamics across different bank size groups. Among the five size groups, IT spending in large banks (asset size $10–250 billion) has been steadily growing, while there is almost no growth in the smallest group (asset size below $0.1 billion). Interestingly, medium-sized banks (banks in asset size bins $0.1–1 billion and $1–10 billion) saw the fastest growth in their IT spending during 2010–2014 but dramatically slowed down during 2015–2019. In contrast, mega banks (asset size above $250 billion) only picked up their IT spending after 2015.

Another noticeable feature revealed by cross-size summary statistics is that smaller banks tend to allocate a higher fraction of their IT budget towards communication technology than larger banks do, while there are no significant differences in the software spending as a share of total IT spending across asset groups. (We will come back to this point in Section 4.2.) As shown in Panel B of Figure 4, the average communication/total spending ratio is 15.9%

[17] The magnitude of IT budget as a share of noninterest expenses in this figure is also in line with Hitt et al. (1999). In their survey banks' IT spending could be as high as 15% of noninterest expenses.

for banks with assets less than $0.1 billion; this ratio monotonically decreases with bank size. A full comparison of the spending on communication and software (as a share of total IT spending) across different bank size group is shown in Table A2.

3.3 Bank IT Investment and Bank Lending

We now perform a comprehensive study on the relationship between banks' IT investments and their (relative) specialization in three major types of loans: commercial and industrial (C&I) loans, personal loans, and agricultural loans. Lending to different types of borrowers often involves distinct ways of dealing with relevant information, due to the different characteristics of borrowers. As a consequence, if banks specialize in different types of loan making, one should expect them to differ in their IT investment profiles.

As a first step, we run the following bank-level regression (we leave the more granular bank-county level analysis for later):

$$\frac{\text{Type S IT Spending}}{\text{Revenue}}_{i,10-19} = \alpha_i + \beta \frac{\text{Type L loan}}{\text{Total loan}}_{i,10-19} + \gamma X_i + \epsilon_i. \tag{1}$$

Here, i refers to bank and the outcome variable of interests is $\frac{\text{Type S IT spending}}{\text{Total IT Spending}}_{i,10-19}$, which is the average investment intensity in a specific type of IT spending as a share of bank i's revenue between 2010 and 2019. The main explanatory variable $\frac{\text{Type L loan}}{\text{Total loan}}_{i,10-19}$, which captures bank i's loan specialization, is measured by the average share of a specific type of bank i' loan relative to its total loan size. Control variables include net-income scaled by total assets, total deposits scaled by total assets, revenue per employee, total equity scaled by total assets and total salaries scaled by total assets. All of the control variables are measured over the ten-year average between 2010 and 2019 at the bank level.

Table 3 reports the estimation results of the regression (1) for C&I loans with the detailed regression outcome including control variables and fixed effects, while for exposition purpose Table 4 only reports the key regression coefficients (i.e., those of specific IT spending shares) for C&I loans, personal loans, and agricultural loans using the same methodology.

A. Commercial and Industrial (C&I) Loans

Table 3 shows the association between C&I loans and different types of banks' IT budgets. Overall, our findings suggest that specialization in C&I loans is most positively and significantly associated with banks' spending in communication technology. A one standard deviation increase in loan portfolio share allocated to C&I loans predicts a 0.053 standard deviation increase in communication budget as a share of total revenue; in dollar terms, this corresponds to an average of $0.14 million spending on communication.

A higher degree of specialization in C&I loans also predicts more spending on hardware, although the magnitude is slightly smaller than that predicted for the communication budget. On the other hand, the coefficient of software spending is insignificant.

Within C&I Loans In the next step, we decompose C&I loans into "Small Business Loans," as measured by a bank's small business lending reported in CRA, and "Other C&I loans." Rows 2 and 3 of Table 4 illustrate how small business loans are compared to other C&I loans in terms of their association with banks' IT spending. while a higher share of small business loans in a bank's loan portfolio is positively and significantly associated with the bank's communication spending, small business loan share is negatively related to the bank's software spending. On the other hand, "other C&I loans"—presumably loans to large firms—are positively associated with software spending, but not with communication spending.

Row 4 of Table 4 further investigates a special type of loan (or lending form)—syndicated loans, in which being a frequent lead bank versus playing more of the role as participant banks. We postpone a more detailed discussion about this comparison to Section 4.2, after we lay out a conceptual framework to think about the distinctive economic meanings of different categories of IT investment in banking.

B. Personal Loans

The second major category of loan type we examine includes personal loans and mortgages. Row 5 of Table 4 reports the associations between specialization in personal loans/mortgages and banks' IT spending. Contrary to commercial and industrial loans, a higher share of loan portfolio allocated to personal loans and mortgages appears to predict more spending on software only. Quantitatively, a one standard deviation increase in loan portfolio share of personal loans and mortgage (about an increase of 7 percentage points) predicts 0.045 standard deviation increase in software budget as a share of total revenue, or an average of $0.65 million more spent on software per year. On the other hand, a higher personal and mortgage loan share does not have qualitatively significant predictive power on communication, hardware, or services budgets.

Within Personal Loans Paralleling our analysis within C&I loans, we also decompose personal loans and mortgages into two subcategories: mortgage refinancing and everything else. As shown in row 6 and row 7 (and compared with row 5) of Table 4 mortgage refinancing, in particular, is positively associated with banks' software spending within the broad category of personal loans (including mortgages). When we study the economic meanings of banks' IT spending in Section 4, this finding motivates us to pay particular attention to mortgage refinancing as a specific type of lending activity in which the processing of hard information plays a critical role.

Additionally, the abundance of mortgage data allows us to gain further insights about the following important aspect of lending activities: originating a new loan versus refinancing an existing loan. The result is reported in Row 8 of Table 4, and we postpone more detailed discussion to Section 4.3.

C. Agricultural Loans

Finally, we examine the association between agricultural loan specialization and banks' IT spending profiles. As shown in row 9 of Table 4, a higher proportion of agricultural loans in a bank's loan portfolio is positively associated with its communication spending. A one standard deviation increase in allocation towards agricultural loans (4.8 percentage points higher) is associated with a 0.056 standard deviation increase in communication budget, or an average of $0.11 million more spending on communication per year.

4 Economics of Banks' IT Investment

Having demonstrated the basic patterns of IT investment in the U.S. banking sector and its interaction with various factors, we now move on to a deeper question: What are the economics behind these banks' IT spending, and in particular, how can they be related—and contribute—to the development of banks' lending technology? The answers to these questions are relevant for a better understanding of how banks develop their lending technologies in the information age.

In Section 4.1, we provide a conceptual discussion of how banks' lending technology during the information age can relate to their investment in information technologies. We then present some motivating evidence, which offers certain clues about the economics of IT spending in banking, based on which we formalize several testable hypotheses.

4.1 Bank Lending Technology and Information

What is a bank's lending technology? While the answer likely depends on the exact definition of "technology," a bank's lending technology could largely be viewed as the bank's ability to deal with information regarding its borrowers. If one can map different types of IT investment into different dimensions of banks' lending technology, then we should expect banks to allocate their IT spending differently according to the type of credit demand they face.

The linkage between the role played by information that facilitates banks' lending activities and banks' lending technology in the information age is important yet unexplored. Broadly speaking, in conducting their lending businesses, banks engage in two types/stages of activities regarding their borrowers' information: information *production/transmission* and information *processing*. More specifically, information *production/transmission*, which is broadly related to soft information in Stein (2002), refers to the stage in which information on borrowers needs to be created or gathered and then relayed to the hands of those who later make decisions based on this information, whereas information *processing*, which is broadly related to hard information in Stein (2002), is more about the stage in which existing (or readily available) information on borrowers needs to be properly utilized by the lender for more efficient decision making.

4.2 Communication Technology and Soft Information

Let us start with information *production/transmission*. When faced with borrowers lenders have never dealt with or borrowers whose information structure is relatively opaque, the first thing they often need to do is to communicate with borrowers, so that they can at least sketch a picture of the borrower with whom they can later examine in detail. Such communications are often essential as the first step in allowing the lender to gather information about their borrowers, either through talking to them face-to-face, or from seeing borrowers' projects for themselves.

Once this first-hand information about borrowers has been gathered, which often can be quite subjective and thus difficult to convey to others, effective transmission of the gathered information within the lending organization can be another crucial factor affecting lending efficiency. This problem associated with the credible transmission of hard-to-verify information within an organization has been recognized in previous studies (e.g., Stein (2002)). Efficient internal communication and exchange is particularly important when the relevant information is relatively soft, which is less objective and often harder to verify by someone who is not the first-hand collector of the information.

One concrete example of how communication technology can help in the two aforementioned dimensions is video conferencing, which has become an important method for banks to communicate with borrowers and customers during the past decade. In the past, banks opened new account openings, originated loan, and resolved problems through in-person visits to the brick-and-mortar branches, but they now use video conferencing technology as it makes the direct—yet virtual—contact between loan officers and borrowers more timely and cost saving.[18] Moreover, video conferencing among the employees within banks has also been welcomed by the banking sector for its advantage in facilitating effective internal collaboration.[19]

Small Business Lending The lending to small business borrowers is one concrete example of such a situation. Sahar and Anis (2016) document that in the context of lending to small- and medium-size enterprises, direct contact with borrowers and frequent visits from loan officers to the borrower allow loan officers to collect and produce soft information. Agarwal et al. (2011) highlight that soft information, such as what the borrower plans to do with the loan proceeds, is always the product of multiple rounds of interactions between the lender and the borrower.[20] Finally, since smaller banks overall issue more loans to small businesses than larger banks do (e.g., Berger and Udell (2002b), Berger and Udell (2006), Hanson and Stein. (2017)), this link between soft information generation and communication technology helps explain why small banks tend to allocate more of their IT budget toward communication spending as shown in Panel B of Figure 4.

Mortgage Initiation The production and transmission of soft information is not only important from the angle of lenders, but also crucial from the perspective of borrowers, especially in the context of mortgage initiation. An industry report shows that 90% of home buyers, especially *first-time* home buyers, cite that they want to directly speak with a loan officer. According to a recent article, Wells Fargo—after spending $500 million on digitizing

[18]See a real-world example of the communication tool "Liveoak" designed for banking services.

[19]See this article from Bankingdive for a detailed description of how video conferencing helps within-bank communication.

[20]The mapping between communication technology and soft information production is also reflected in the relation between whether a bank serves lead banks frequently in loan syndications and its various IT spending, as shown in Table 4. The nature of interactions between lenders and borrowers differs if the lender is a lead bank as opposed to participant banks: being a frequent lead bank requires frequent communication, reporting, coordination among borrowers and peer lenders.

mortgage experiences—admitted that "73% of home buyers wanted assurance that they could speak with a real person through the process." Mobile phone devices, desktop telephone sets, Wi-Fi transmitters, and video conferencing devices are all important communication infrastructure and ensure communication between borrowers and lenders for the generation of soft information.[21]

Lead versus Participant (in Syndicated Loans) The syndicated loan market provides a special environment to explore the relationship between communication technology and soft information production. In syndicated loan lending, the nature of interactions between lenders and borrowers differs drastically if the lender is a lead bank as opposed to being a participant bank (Sufi (2007), Ivashina (2009)). Lead banks are mandated by borrowers to acquire other lending participants, conduct compliance reports, and negotiate loan terms. After the loan is issued, they also have the responsibility to conduct monitoring, distribute repayments, and provide overall reporting among all lenders within the deal. In this regard, lead banks' job performing involves significantly heavier effort in information generation and sharing as well as coordinating negotiations than that of a participant bank. In short, effective communication plays a more central role in the functioning of lead banks than that of participant banks.

The above conceptual difference between the roles played by lead banks and participant banks naturally leads us to empirically examine whether the frequency with which a bank participates in syndicated loans as a lead arranger can predict the bank's IT investment behavior, with the regression framework in Eq. (1) in Section 3.3. As shown in Table 4 row 4, a bank's investment in communication technology exhibits a strong positive association

[21]Not only does communication infrastructure help soft information generation at the loan origination stage, but it also greatly enables lenders to closely monitor borrowers' business conditions after the loan is issued, especially for information that is not directly observable or verifiable. A concrete example is agricultural loans; we have shown toward the end of 3.3 that agricultural loans are positively associated with communication technology investment. Indeed, effective monitoring of agricultural loans involves a good estimate of farmers' income and riskiness; but these are dependent on observing what is going on at the farm—(e.g., are there pests or floods? is the weather normal?). Traditionally farms are monitored through frequent in-person visit to the farmland by loan officers. With advances in technology, more and more of this monitoring relies on video conferencing and even satellite image generation and transmission. See this article describing the difficulty of monitoring agricultural borrowers faced by traditional lenders.

with the frequency of that bank serving as lead bank in syndicate loans, whereas a negative association emerges between the bank's software spending and its frequency serving as a lead bank.

We hence propose the following hypothesis as to how banks' investments in IT can be mapped to their lending technology development. We will examine their causal relationship in our later analysis.

Hypothesis I

Banks' investments in communication IT are more associated with improving their ability to produce and transmit soft information. Specifically, in the context of small business lending, banks will increase their spending on communication technology given an increase of credit demand from small business borrowers.

4.3 Software Technology and Hard Information

We now move to information *processing*. Once information has been produced (by the lender itself) or is readily accessible (via the third party), the next concern for the lender is how to most efficiently utilize this information to make wise decisions. In the context of credit allocation, banks need to be able to properly evaluate the creditworthiness of their borrowers to determine loan amounts and rates. More specifically, when banks are faced with borrowers whose information structure is relatively transparent or borrowers they already have some knowledge about from previous interactions, lending decisions simply boil down to efficient utilization and processing of the available information.

Accurate evaluations of borrowers' credit risk often require complicated modeling and simulations, which are often impossible without the support of sophisticated software tools. In terms of facilitating lending activities, software is particularly useful for dealing with existing or readily accessible "hard" information. Banks have actively adapted new software-based technologies to store, organize, and analyze large chunks of loan applicants' data, or data augmented by other software. In this regard, investing in software can greatly help banks to more promptly and accurately process the available information so that they can make their lending decisions in a more efficient and reliable way. By contrast, several decades ago all credit application information had to be stored on paper application forms, then reviewed and processed manually by loan officers.[22]

From the banks' perspective, software differs from communication technology in that communication devices can facilitate the gathering and dissemination of information, whereas software is more targeted at utilizing information that is readily available at hand.[23] Because of this difference, software as a category of banks' IT budgets should be more relevant in dealing with loans that primarily involve the processing and assessment of existing information that is relatively "hard." In practice, a specific form of software technology product is the credit scoring software utilized by banks when making refinancing decisions. Some concrete examples of these credit scoring software include SAS Credit Scoring, GinieMachine, and RNDPoint.[24]

Refinancing versus Origination (of Mortgage Loans) The discussion above suggests that software IT should help greatly in refinancing existing loans as opposed to originating new loans. Recall Section 3.3 analyzed the relationship between IT spending and banks' loan specialization; there, we find mortgage refinance stands out as a special type of loan that appears to be particularly strongly associated with banks' spending on software, as shown in rows 6 and 7 of Table 4. To sharpen our understanding of the role played by software in lending technology, we move one step further and conduct a similar analysis within the mortgage lending business, by splitting mortgage business into mortgage origination and

[22]For example "nCino" is operating system software that allows financial institutions to replace manual collection of loan/account applications with automated and AI based solutions. "Finaxtra" and "Turnkey" are both comprehensive loan origination systems that offer solutions for the whole lending process.

[23]This difference also explains why fintech companies, who often serve as the suppliers of new banking software products, have expanded dramatically in the mortgage refinance market (e.g., Fuster et al. (2019), Seru (2019).)

[24]To use these software, banks usually just need to import available demographic and historical information on borrowers, then the software calculates credit scores and conducts statistical tests for robustness using AI and machine learning methodologies, which save banks from tedious manual work and quicken the processing.

mortgage refinancing. We find that if a bank is a frequent "refinance" lender in the mortgage market versus serving as an originator, which is measured by the percentage share of refinance loans issued by the bank within its total mortgage lending in the HMDA data, the bank also tends to spend more on software. The detailed results are reported in row 8 of Table 4. Finally, as expected, contrary to the positive significant association between software spending and mortgage refinance, communication spending shows no correlation with activity in mortgage refinance business.

Motivated by these findings, we propose and test the following hypothesis relating software IT spending and hard information processing in commercial banks. Note, this hypothesis is also consistent with the recent literature showing that fintech expansion is particularly pronounced in the refinancing segment of the mortgage, auto loan, and student loan markets (Drechsler et al. (2016)), as fintechs typically rely on readily available hard information.

Hypothesis II

Banks' investments in software IT is more associated with improving their capability to process hard information. Specifically, in the context of mortgage refinancing, banks are likely to increase their spending on software IT when facing an increased credit demand for mortgage refinancing purposes.

4.4 Labor Employment and Bank IT Investment

In addition to these two aspects of banks' lending technologies and their relation to banks' investments in IT, we also pay attention to a third dimension in understanding the economics of how banks develop their lending technologies: the labor and employment in the banking sector. In tandem with the widespread application of automation and artificial intelligence, there has been ongoing debate about how this technological progress might impact the demand for a human workforce. In the context of banking, if we treat banks' labor employment as a traditional input that deals with information production and information processing, one question naturally arises: How would the adoption of new technology that deals with information production/processing impact the job security of these bank employees? In particular, will banks' investments in IT substitute out or complement bank employees who perform information related tasks?

Given the complicated nature of interaction between IT-related employment and software, together with rich economic forces at play (say factor prices), it is unclear a priori if we should expect these two to be substitutes or complements. However, because generating new and soft information would still have to rely (at least to some degree) on human labor, there is much less substitution/complementarity between IT-related employment and communication technology investment.

We have presented some empirical patterns that offer preliminary answers to both questions. Recall that we have learned from Figure 3 that banks with lower IT-related labor hiring tend to have a higher growth rate in their total IT spending. Figure 5 further examines communication spending and software spending separately, and shows that the time trend pattern documented in Figure 3 is mainly driven by banks' spending on software technology—not communication spending at all.

Therefore the data seem to suggest that, while indeed there is no relation between IT-related employment and communication spending, there is a substitution effect between IT-related employment and software spending in the banking industry. This could be driven by many possible mechanisms: for instance, superior computing power and algorithmic calculation would enable IT to effectively take over the task of processing relatively hard information. We summarize this section by developing the following hypothesis, which again will be formally tested in Section 5.3.

Hypothesis III

Banks' adoption of information technologies has an asymmetric relationship with banks' IT related employment. Specifically, i) investment in software IT is a substitute for banks' IT-related employment, and therefore, banks tend to increase (decrease) their spending on *software IT when the supply of IT-related labor is scarce (abundant); yet ii) no such substitution effect exists between banks' investment in communication IT and their IT-related employment.*

5 Empirical Designs and Tests

In this section, we exploit policies that affect geographic regions differentially to identify the causal relationships highlighted in the hypotheses developed in Section 4.

5.1 Soft Information Production and Bank IT Investment

We first focus on *Hypothesis* I, which posits that banks should invest more in their communication technology when faced with rising demand for credit that relies heavily on the production/transmission of soft information. One typical example for such soft information–driven credit is small business lending.

Soft information production plays a critical role in the small business lending sector (Berger and Udell (2002a), Liberti and Petersen (2018)). Small business loans refer to a special type of bank loan where banks mainly deal with young and opaque firms who often have only limited credit history; Section 3.3 has shown a positive correlation between specialization in small business lending and banks' spending on communication technology (Table 4, row "C&I loans"). Following this logic, we regard increased credit demand from small business borrowers as a demand for more intensive production of soft information. The goal of our identification analysis in this section is then to establish a causal relationship between a higher demand for credit from small business borrowers and an increase in banks' spending on communication technology.

Our identification strategy relies on an event-driven credit demand shock that hits the U.S. banking sector heterogeneously across different regions in terms of small businesses' credit demand. This feature allows us to extract and utilize variations that come from banks' arguably exogenous exposures to such credit demand shocks. To motivate our approach, we first present a set of scatter plots displaying banks' IT investment patterns and lending technology adoptions when they operate in different economic environments. The two upper panels in Figure 6 display correlations between banks' IT investments and the share of small business in local counties. There, we see that a greater presence of small businesses (as measured by establishment with $\leq$ 5 employees) in a local county is strongly positively correlated with communication spending intensity of banks operating in the county, but not with software spending.

Constructing Shifter in Small Business Credit Demand We utilize a special program called the "Small Business Health Care Tax Credit" in the Affordable Care Act enacted between 2014 and 2015, which was aimed at encouraging small businesses to provide health care coverage to their employees. The program offers tax credit to small business employers who pay health insurance premia on behalf of employees. To qualify for the tax credit, the employer needs to (1) have 25 or fewer employees; (2) pay average wages less than \$50,000 a year per full-time equivalent; (3) pay at least 50% of its full-time employees' premium costs; and (4) have provided a health plan to employees that is qualified under the SHOP program coverage requirements.[25]

There are many reasons for why the launch of this program could boost local small businesses' credit demand.[26] For instance, small business owners who had not provided their employees health coverage before the availability of the program might now be able to borrow from banks and fund their working capital. What is more, with the tax credit subsidized for

[25]See the guidance here directing to the introduction of the policy. According to the IRS, small business employers should apply for the tax credit by filling in Form 8941. The tax credit can be carried backward or forward to other tax years. Also, since the amount of the health insurance premium payments is more than the total credit, eligible small businesses can still claim a business expense deduction for the premia in excess of the credit, which means both a credit and a deduction for employee premium payments. Small businesses receive credit on a sliding scale. The smaller the employer, the bigger the credit. The tax credit is highest for small companies with fewer than 10 employees who receive an average annual salary of \$25,000 or less.

[26]Previous literature in economics has documented increases in labor demand, firm expansion, productivity growth, etc. after the implementation of corporate tax cuts or the launch of subsidies (Cerqua and Pellegrini (2014), Rotemberg (2019), and Ivanov et al. (2021)).

them, small businesses could potentially initiate desired expansion and development projects from which they had previously been financially constrained.

While the implementation of this program tends to shift up credit demand from small business borrowers universally across the U.S. economy, the exposure to this credit demand shock may vary substantially across different regions, depending on their pre-event characteristics. In particular, the number of qualified establishments at (or right before) the event date, which features substantial variation across different counties, is a key determinant for rising credit demand from small business borrowers in the local area.[27] Such variation in the pre-event number of qualified establishments can thus help us isolate variations in small business credit demand across regions; since the policy only explicitly targets small businesses, its impact on other types of credit demand would be relatively limited or at least less direct.

Empirical Design: 2SLS Regression Following our discussion above, we run the following 2SLS regression which uses "Qualified Small Businesses" (QSB) in 2013 as an instrumental variable of the local county's exposure to the program:

$$\begin{aligned} \Delta \ln(\text{CRA})_{i,c,post} &= \mu_i + \mu_1 \ln(1+\text{QSB})_{c,pre} + \mu_2 X_{i,c} + \epsilon_{i,c} \\ \Delta \ln \text{IT}_{i,c,post} &= \alpha_i + \beta \Delta \widehat{\ln(\text{CRA})}_{i,c,post} + \gamma X_{i,c} + \epsilon_{i,c}. \end{aligned} \tag{2}$$

The first equation in Eq. (2) is the first-stage regression. The outcome variable $\Delta\ln(\text{CRA}_{i,c,\text{post}})$ is the change in the logarithm of bank i's small business loans in county c in the three-year time window after the program compared to its small business loans in the same county three years before. The instrumental variable $\ln(1+\text{QSB})_{c,pre}$ is the logarithmic of the total number of small businesses with fewer than 20 employees in 2013 before the policy shock; due to data limitations we pick the cut-off "20," as opposed to "25" as specified by the

[27] Qualified establishments are small businesses with fewer than 25 employees, per the program's stipulations.

program.[28] In the second stage, we regress $\Delta \ln \text{IT}_{i,c,post}$, which is the change in logarithm of a specific type of IT spending of bank i in county c after the program implementation compared with before, on the fitted value from the first stage. In both stages, X represents a vector of control variables that includes the bank fixed effect together with several bank-county-level control variables. We have included the total number of establishments in 2013, which controls for the total local credit demand (not just from small businesses).[29]

Estimation Results We report the estimation results of (2) in the first three columns of Table 5. Column (1) shows the regression in the first-stage regression, and columns (2) and (3) show results of the second stage.

Column (1) shows a strong first stage result with an F-statistic of 15.18, which is well above the conventional threshold for weak instruments (Stock and Yogo (2005)). As reported in columns (2) and (3), we find no significant response in banks' software spending after the program launch, but there is a positive and statistically significant response in banks' communication investment across counties. In particular, banks who saw a one standard deviation higher growth in their small business loan making, due to the higher shock exposure of the counties in which they operated, experienced a 0.0745 standard deviation higher growth in their communication spending. This translates to a 26% higher communication spending, or an average of $67,830 more per year, compared with banks located in other lower exposure counties. Note, our estimation includes bank fixed effects, so the above result applies to within-bank, but cross-county variations.

Comparison: OLS Estimates To gain more insights about our 2SLS estimates, we also compare them to the estimates from the OLS regression, with results reported in Columns

[28]The "County Business Pattern" database provides categorization of small businesses sizes (number of employees) based on the following cut-off; less than 5, 5-9, 10-19, 20-49, 50-99, 100-249, 250-499, 500-1000, more than 1000. We chose the closest cut-off, which is "fewer than 20."

[29]The main control variable is "Revenue per Employee" at the bank-county level. The total revenue is at bank-county-level from Harte Hanks, and total number of employees is from Harte Hanks. County level control variables include the labor force, population growth rate, and total number of establishments.

(4)–(5) of Table 5:

$$\Delta \ln(\text{IT})_{i,c,post} = \alpha_i + \beta \times \Delta \ln \text{CRA}_{i,c,post} + \mu_c + \gamma X_{i,c} + \epsilon_{i,c}. \tag{3}$$

Qualitatively, OLS estimates are similar to those obtained from the 2SLS method: within a bank, its branches in counties seeing a higher growth rate in small business loans invest more in communication than other branches, but not in software spending.

Quantitatively, the magnitudes of the OLS coefficients are significantly smaller. One potential explanation for such a downward bias in OLS estimators could be the following "omitted variable" problem, in which counties with faster growth in small business loans are those with even faster growth in some unobservable economic variables—say, mortgage demand—that drives local banks to spend less on communication. More specifically, if mortgage demand is correlated with demand for small business loans, and if banks have a fixed amount of IT budget each year, then they will allocate more IT spending—say, software—to cater to mortgage demand. The omitted-variable problem then leads the OLS estimator to underestimate the responsiveness of communication spending towards small business loan demand. The cross-region shifter constructed above based on the tax policy targeting only small businesses thus allows us to isolate the variation in small business credit demand from that of other types of credit.

5.2 Hard Information and Bank IT Investment

In this section, we identify the causal linkage between credit demand that requires intensive processing of hard information and banks' investments in software technology, which concerns *Hypothesis* II in Section 4.3. By definition, "hard" information refers to the type of information that is existent, can easily be quantified, and does not require further verification. In terms of lending, loan origination and refinancing provide an ideal setting to investigate the relationship between "hard" information and banks' lending technology investments.

Mortgage refinancing is a special type of loan that primarily involves processing existing information, as refinance applicants by definition have already been granted loans before. Typical refinance applications require applicants to provide their W-2, pay stubs, financial account statements, most recent monthly statement for their mortgage, and sometimes the appraisal documents of their house. Many banks offer complete online refinance applications so that borrowers do not even need to visit bank offices in person. Oftentimes, in direct contrast to the origination of mortgages, these types of procedures can be done solely through digitization software and risk assessment software.

Similar to Section 5.1 we motivate our cross-region identification with a set of scatter plots displaying how banks' IT investments correlate with local mortgage refinance demand. As shown in the lower two panels of Figure 6, the average refinance growth rate in a local area is correlated with software spending, but not much with communication spending.

Constructing Shifter in Mortgage Refinance Demand For exogenous sources of variation in mortgage refinance demand across different regions, we utilize the post-crisis period during which the mortgage interest rate is systemically low and aggregate demand for mortgage refinancing is high. Figure A2 displays the evolution of nationwide average mortgage interest rates before and after the financial crisis; we observe that the aggregate 30-year mortgage rate (blue line) plummeted from the pre-crisis level of 6.5% to 3.75%.

The nationwide mortgage rate decrease has prompted existing homeowners with mortgage balances to refinance their mortgages, and an important determinant of homeowners' refinancing propensity would be the pre-crisis mortgage characteristics in place before the low-interest episode kicks in. For the three-year time window between 2010 and 2012, we construct the following county-level measure that captures the heterogeneity of each county's refinance propensity during 2010–2012:

$$\text{Payments gap}_c = Ave.(\text{Payments}_{\text{old interest rate}} - \text{Payments}_{\text{new interest rate}})_c.$$

To put this into words, we calculate the average total remaining mortgage payment gap under old versus new interest rates at the county level. In constructing this measure, we use information about all local household outstanding mortgage loans and their mortgage rates at issuance by county since 2000. We remove loans that were defaulted on or prepaid to ensure that the measure captures only refinance propensity from local households with outstanding loans.

Importantly for our identification purposes, the county-level payment gap measure as constructed above features significant variation across regions. Eichenbaum et al. (2018) also showed that the long-term low interest rate had a substantial and heterogeneous impact on regional refinancing by households located in different states, depending on how much those households could save on interest expenses by refinancing. This variation in local homeowners' payment gaps from interest savings allows us to construct an exogenous shifter on the mortgage refinance demand faced by banks operating in the local economy. Other work such as Di Maggio et al. (2017) uses similar sources of regional heterogeneity to proxy for refinance propensity.

Empirical Design: 2SLS Regression The regression specification using Payments gap_c as the instrumental variable is:

$$\begin{aligned} \ln \text{Refinance}_{i,c,t} &= \mu_i + \mu_1 \text{Payments gap}_c + \mu_2 X_{i,c,t} + \epsilon_{i,c,t} \\ \left(\frac{\text{Type S IT Spending}}{\text{Revenue}}\right)_{i,c,t} &= \alpha_i + \beta \ln \widehat{\text{Refinance}}_{i,c,t} + \gamma X_{i,c,t} + \epsilon_{i,c,t}. \end{aligned} \tag{4}$$

The first equation in Eq. (4) is the first-stage regression using Payments gap_c as the instrumental variable. The left-hand side variable in the first stage is the average of the logarithmic refinance loan volume of a bank i in county c during 2010–2013, compared with 2007–2009. In the second stage, we regress IT spending intensity of bank i in county c on the fitted value of $\Delta \ln \text{Refinance}_{i,c}$, which identifies whether IT investment specialized in processing existing information increases when there is higher local refinance demand.

Estimation Results Table 6 reports our estimation results. Consistent with the literature, the instrumental variable "Payments gap_c" predicts mortgage refinancing activities across different counties quite well, with extremely high F-statistics (2,408).

Columns (2) and (3) show the results of second-stage regressions. A one standard deviation increase in mortgage refinancing lent out by a bank (due to its local exposure to high refinance savings) leads to a 0.0672 standard deviation increase (around 8% higher on average) in software spending intensity measured as software spending scaled by total revenue compared with other banks located in potentially low-exposure counties, corresponding to \$0.16 million per year. This result can also be interpreted as the within-bank cross-county impact of mortgage refinance demand on banks' software spending. On the other hand, communication spending intensity as a share of total revenue does not demonstrate significant changes in response to the refinancing demand captured by the predetermined refinance propensity during the low mortgage rate episode.

Comparison: OLS Estimates We conduct the OLS regression as follows and report the results in the last two columns of Table 6:

$$\frac{\text{Type S IT Spending}}{\text{Revenue}}_{i,c,t} = \alpha_i + \beta \times \ln \text{Refinance}_{i,c,t} + \mu_t + \gamma X_{i,t} + \epsilon_{i,c,t}. \tag{5}$$

Similar to the comparison between OLS and 2SLS estimates we reported in Section 5.1, we find qualitatively similar yet quantitatively smaller OLS estimates.[30] The reason is similar to that discussed in the previous section. Counties seeing more mortgage refinance issued by local banks could also have other loan demands that recovered more significantly during the post-crisis period (say, commercial and industrial loans, agricultural loans or even mortgage origination, which might tilt banks' IT budget towards other types of IT spending). Likewise, this omitted-variable problem will make OLS underestimate local banks' software spending response towards mortgage refinance propensity. Our instrumental variable used in the 2SLS

[30]Table A4 shows the results of the same OLS specification with bank, year and county fixed effects and bank×year and county fixed effects.

method addresses this issue.

5.3 Bank IT Investment and Labor

As firms adopt technology and automate tasks, the effects on their labor employment have been a focal point of recent economic studies. Labor employment in the banking sector is also subject to, if not more, the impact of fast-developing information technologies.

In this section, we move on to *Hypothesis* III and study the relationship between banks' IT investments and their labor employment outcomes. Specifically, we investigate whether banks' IT spending is a substitute or complement when banks face supply shocks on IT-related employees. While the time trend plots displayed in Section 4.4 provide us with a rough answer as to the economic nature of the relationship between IT investment and IT-related labor employment, it suffers from a standard omitted variable problem. For a more causal linkage from IT-related employment to IT spending, we exploit variations in the supply of skilled labor across different regions. More specifically, we examine whether banks located in counties with more abundant supplies of high-skilled labor will exhibit different IT investment patterns compared with those operating in other areas.

More specifically, following the labor literature (e.g., Moretti (2004), Liu (2015)) we instrument IT-related employee growth using the presence of land-grant colleges in the local area, because college graduates are the the main source of IT-related employees in the local banking sector. Land-grant colleges are universities supported by the first federal program to support higher education.[31] The local availability of a land-grant college is a strong predictor of skilled labor supply in local area (Moretti (2004)) and is shown to be unrelated to other local economic condition changes (Kantor and Whalley (2019)).

[31] In 1862, the U.S. Congress passed the Morrill Act and granted federally controlled land so states could establish colleges that focus on teaching agriculture, science, and engineering. In 1890 and 1994, further legislation expanded this initiative. Altogether, there are 106 land-grant colleges in the United States, many of which have grown into large public universities and educate almost one-fifth of degree-seeking students in the United States.

We run the following 2SLS regression at the bank-county level:

$$\begin{aligned}
\Delta\,(\text{IT Emp/Total Emp})_{i,c} &= \alpha_i + \gamma \cdot \text{Land-grant college availability}_c + \mu X + \epsilon_{i,c}; \\
\Delta\text{Software or }\Delta\text{Communication/Revenue}_{i,c} &= \alpha_i + \beta \cdot \Delta\,(\widehat{\text{IT Emp/Total emp}})_{i,c} + \phi X + \epsilon_{i,c}.
\end{aligned}$$

Here, we first construct IT Emp/Total $\text{Emp}_{i,c}$ as the bank-county's IT employee share of its total employees; then Δ $(\text{IT Emp/Total Emp})_{i,c}$ is the change of this variable from 2010–2014 to 2015–2019. We measure the local availability of land-grant colleges, which serves as our instrumental variable, by constructing a dummy Land-grant college availability_c which either equals 1 if there is a land-grant college located in the county, or (Ln min-distance) which is the logarithm of the distance between this county and the nearest land-grant college.

Table 7 shows the results of the above regression specification, with Panel A for instrumental variable being a dummy and Panel B for the logarithm of distance. Column (1) reports a strong first-stage results (with two F-statistics at about 300) with the right signs (i.e., availability of land-grant college strongly predicts local banks' IT employees growth).

Columns (2) and (3) in Table 7 report the second-stage regression. Banks located in counties with faster (slower) growth in IT-employees—due to greater (less) land-grant college availability—see significantly slower (faster) growth in software spending, while there is no statistically significant difference in communication spending growth compared to counties with less land-grant college availability. Quantitatively, a one standard deviation increase (decrease) in IT employee share due to the availability of land-grant colleges leads to a 0.045 standard deviation decrease (increase) in software spending as a share of revenue, which is about 5.13% of the branch-level revenue and about 5.51% of local branches' noninterest expenses. One natural economic channel behind this result is local wages: when IT labor is scarce (due to low supply of college graduates) in a local economy, banks' labor cost of hiring IT-employees goes up—which induces banks to increase their purchases of software IT.

While we observe a strong effect of the availability of IT-employees on banks' software spending, there is no such effect on banks' communication spending. From the perspective of our paper, this is perhaps because all employees, whether IT-related or not, rely on communication technology that has more to do with soft information production/transmission. We leave future research to explore further this interesting "asymmetry" in the relation between IT-employment and IT spending.

6 Conclusion

Development of information technologies over the past several decades has dramatically revolutionized the way lending is conducted by the traditional banking sector. In this paper, we provide the first comprehensive study of banks' IT spending, which we view as banks' investments to develop and improve their lending technology.

The detailed IT spending profiles available in our unique data set enable us to uncover several novel findings. First, at the aggregate level, we document an overall fast growing trend in banks' spending on modern information technologies, and how that varies across banks of different sizes. Second, we show that the different types of information technology are closely related to the information natures embedded in different types of loan making. More specifically, the production and transmission of "soft" information, which plays a crucial role in conducting small business lending, is strongly associated with banks' communication spending; by contrast, "hard" information processing, which is most relevant for conducting mortgage refinancing, is strongly associated with banks' software spending. Finally, we provide causal evidence for the linkage between the credit demand associated with different information natures and banks' IT spending responses using granular bank-county level data, as well as the substitute/complement relationship between the labor employment and IT investment in the U.S. banking sector.

Our findings open up several important further questions. For instance, how does endogenous technology adoption in the banking sector transform the banking/credit market structure? Does the presence of fintechs impede or spur the banking sector's technology adoption? How do technology upgrades in the banking sector affect banks' deposit-taking activities, loan outcomes, properties of credit cycle, and monetary policy transmission? We leave it to future research to provide answers to these questions.

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Figure 1. IT Spending: Time Trend

This figure shows the time trend of banks' IT spending from 2010 to 2019. The solid line shows the weighted average of banks' IT Spending as a share of banks' total income; the dashed line shows the weighted average of banks' IT spending as a share of banks' total income. “Revenue” is constructed using the item RIAD4000 in Call Report, and ”Non-interest Expense” is the non-interest expenses reported by item RIAD4093 in Call Report.

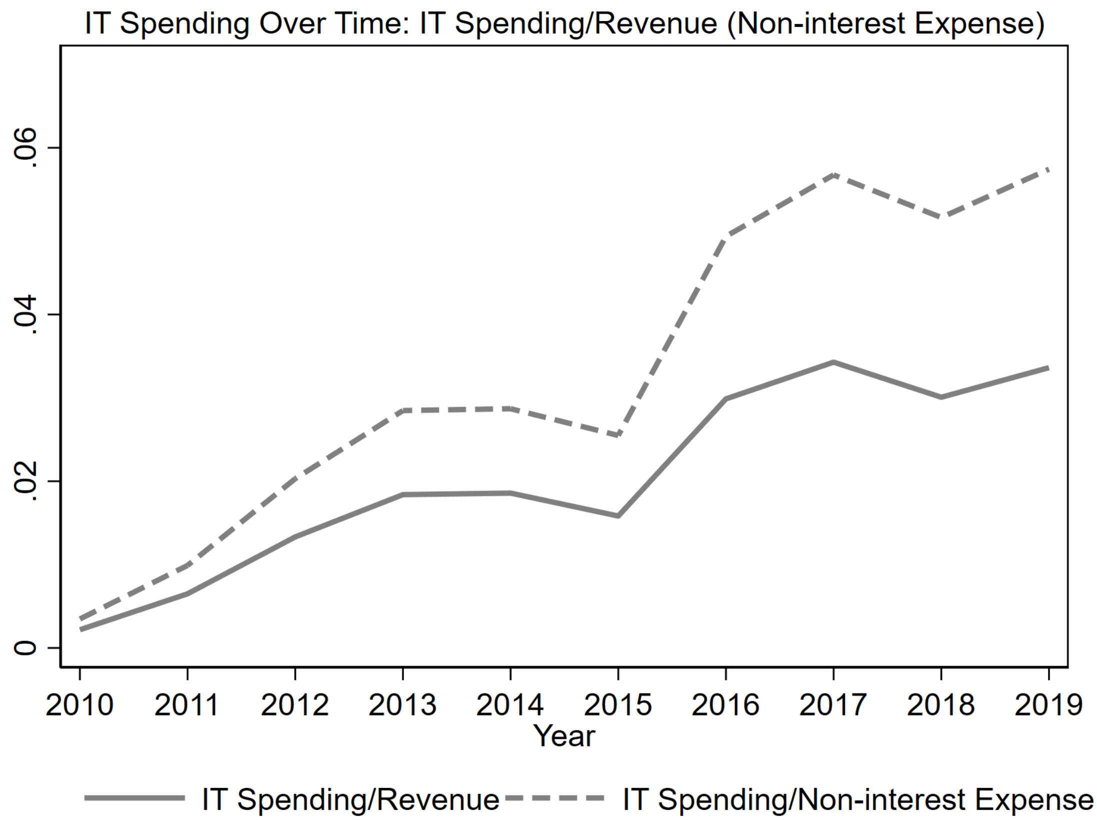


Figure 2. Fintech Presence and Banks' IT Spending

This figure shows the relationship between banks' IT spending and the presence of Fintech companies in local economy. The y-axis is the county-level "Total IT spending/Revenue" of local banks. Based on the average Fintech lending share in mortgage market of a county during 2010-2019 used in (Fuster et al. (2019)), we define high and low fintech presence as counties with above-median and below-median fintech lending share in local mortgage market, respectively.

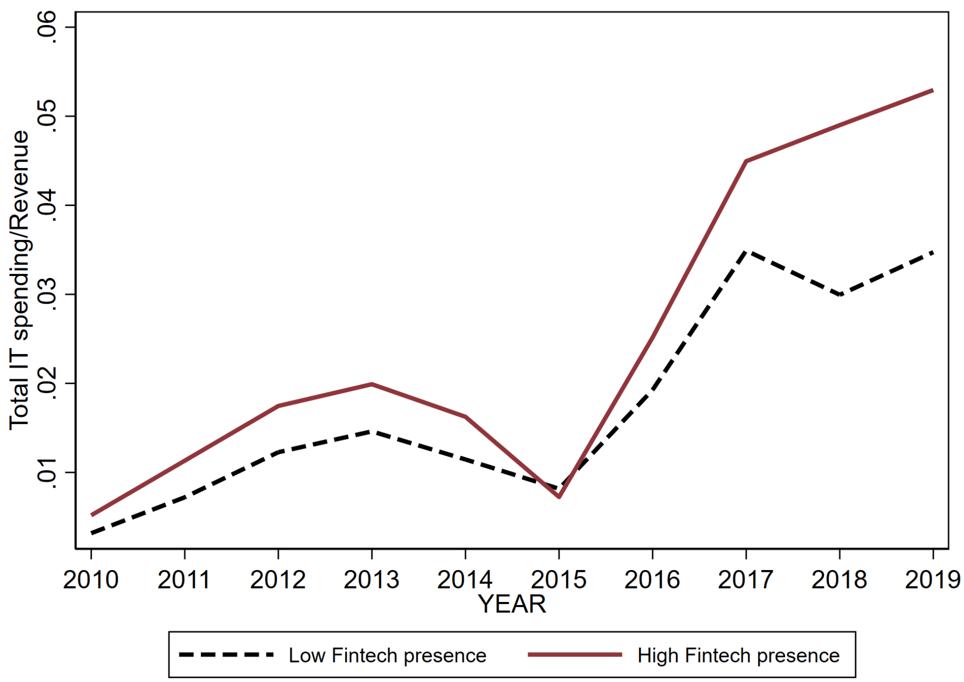


Figure 3. Bank Employment Trend and Banks' Total IT Spending

The figure below shows the over-time trend of banks' IT Spending as a share of revenue for banks with high IT employee share and banks with low IT employee share. The solid line shows the banks' Total IT spending/Revenue, weighted by banks' asset sizes for banks whose IT employee share is above the 80-th percentile of that among all banks between 2010-2019. The dashed line shows the banks' Total IT spending/Revenue, weighted by banks' asset sizes for banks whose IT employee share is below the 20-th percentile of that among all banks.

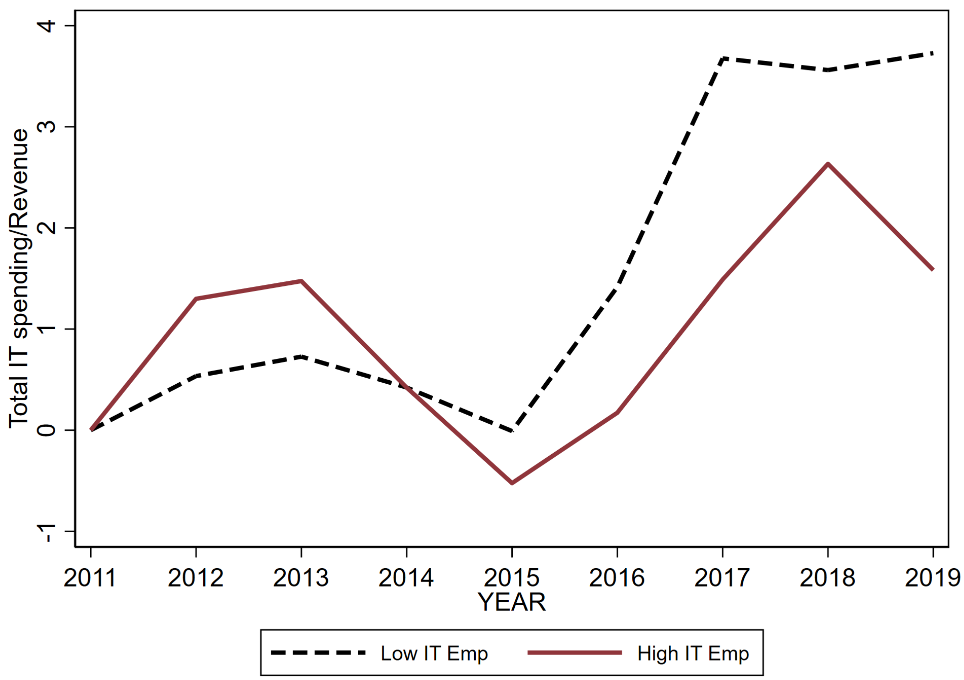
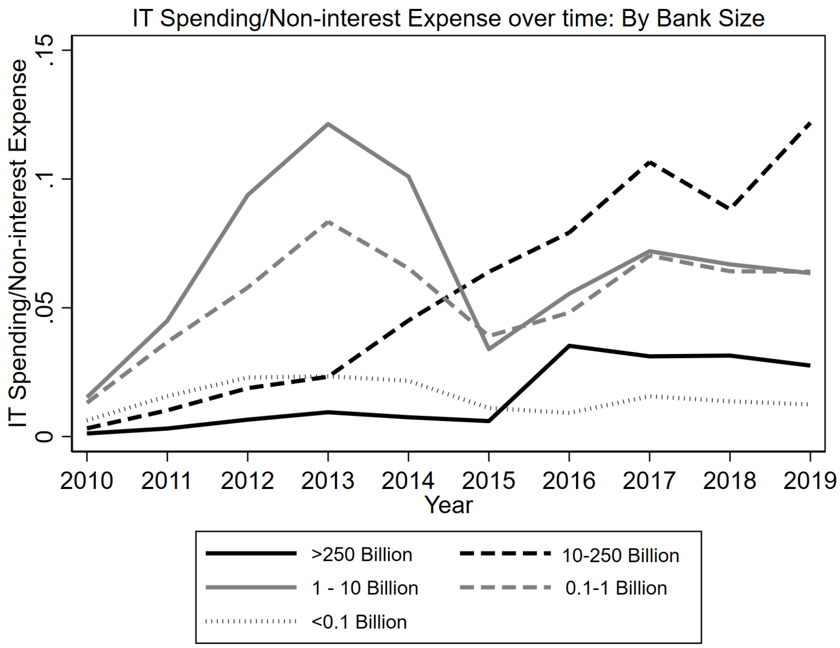
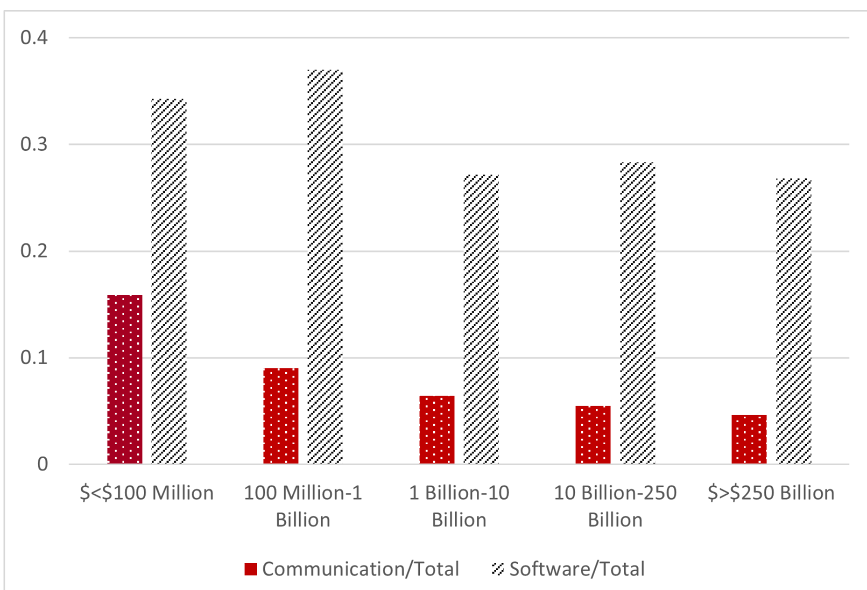


Figure 4. IT Spending Time Trend and Composition, by Bank Size

The figures show the time trend of banks' IT spending from 2010 to 2019 by the five categories of bank asset size groups (Panel A) and the differences in composition of IT spending by bank size groups (Panel B). In Panel A, The vertical axis is banks' total IT spending scaled by non-interest expenses. The asset size groups are categorized based on a bank's average asset size during 2010 and 2019. Non-interest expenses are calculated using banks' balance sheet item "RIAD4093" in Call Report. In Panel B, the shaded bars show the average proportion of total IT budget spent on communication and software across bank size groups.



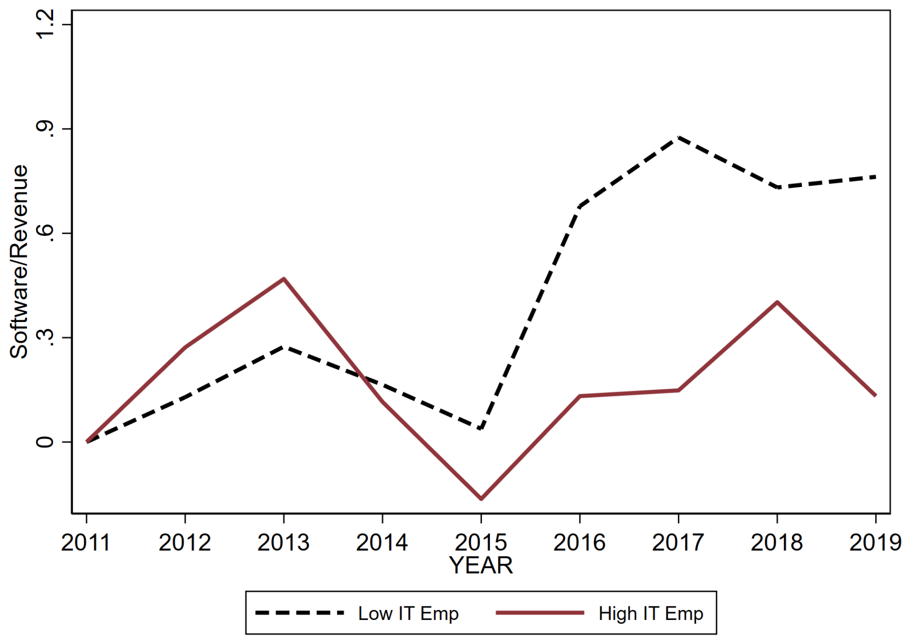
(a) Panel A



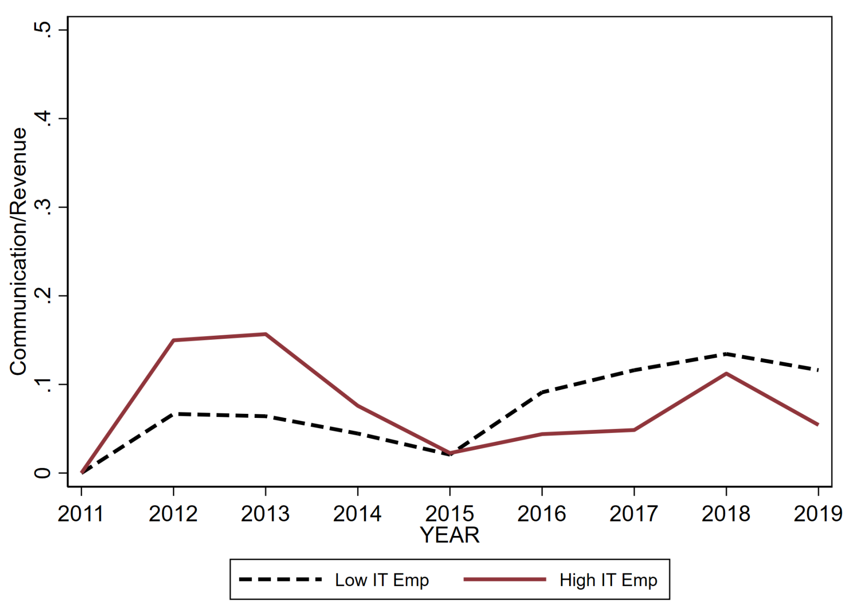
(b) Panel B

Figure 5. IT-related Labor and IT Spending on Software versus Communication

The figures below show the over-time trend of banks' software spending and communication spending as a proportion of revenue, for banks with high IT employee and with low IT employee. "ln IT Employees" shows the weighted average of logarithm of IT related employees, weighted by banks' asset sizes. The solid line shows the banks' software spending or communication spending/Revenue, weighted by banks' asset sizes for banks whose IT employee share is above the 80-th percentile of that among all banks between 2010-2019. The dashed line shows the banks' software spending or communication spending/Revenue, weighted by banks' asset sizes for banks whose IT employee share is below the 20-th percentile of that among all banks.



(a) Panel A



(b) Panel B

Figure 6. IT Spending Profile and Local Profiles

The figures below show the association between banks' IT spending pattern and local business characteristics. The two figures in the first row shows the bin-scatter plot of the association between the proportion of small businesses with less than or equal to 5 employees and the local banks' communication spending/software spending as a share of their total revenue. The IT spendings are weighted by banks' revenue in the county. The two figures in the second row show the scatter plot of association between counties' mortgage refinance growth rate and local banks' communication/software spending as a share of their total revenue between 2010-2019. All variables in the figures are standardized. Variables on both panels of figures are winsorized at 5% and 95%.

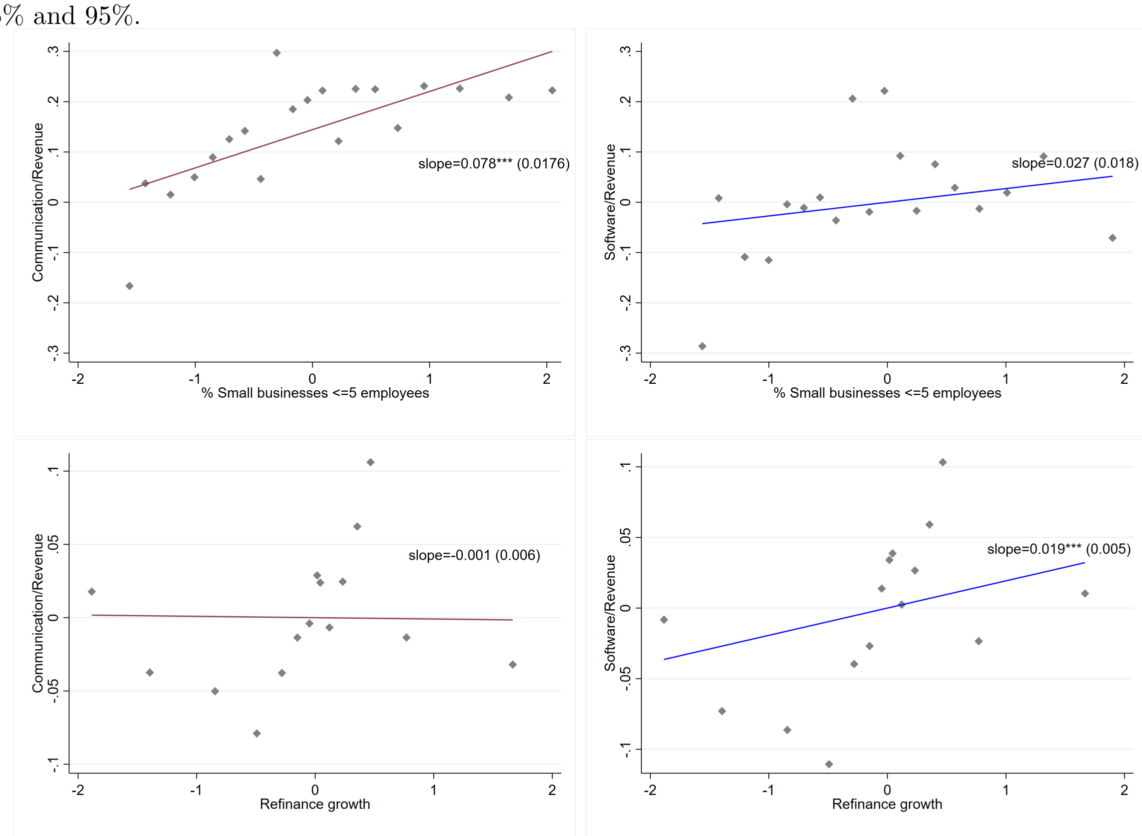


Table 1. Sample Coverage

This table demonstrates the sample coverage of banks across five categories of banks' size groups. All banks in the sample are commercial banks. The Call Report bank population includes only commercial banks ("Charter Type" being 200) following FFIEC definition. The first two columns shows the number of banks and the average asset sizes of banks in our sample, across five size groups. Column 3 and column 4 show the total number of banks and average asset sizes of all banks in the Call Report. Column 5 shows the percentage of sample coverage in terms of frequency compared with the population in Call Report, and column 6 shows the percentage of sample coverage in terms of total asset size compared with the population in Call Report.

Coverage of data	Sample		Call Report		Freq %	Asset %
Average Assets 2010-2019 (Billion)	Num banks	Ave Assets	Num banks	Ave Assets		
>$250 Billion	6	1184.24	7	787.34	85.71%	96.66%
$10 Billion–$250 Billion	88	42.30	106	43.69	83.02%	73.22%
$1 Billion–$10 Billion	474	2.90	590	2.78	80.34%	89.43%
$100 Million–$1 Billion	942	0.40	4161	0.32	22.64%	29.44%
<$100 Million	296	0.06	2048	0.05	14.45%	14.23%

Table 2. IT Spending Summary Statistics

This table shows the summary statistics of banks' IT Spending. Total IT Spending is the sum of all types of IT spending in millions of dollars. No. of IT employees is the total amount of IT-related employees. IT Spending/Revenue is total IT Spending scaled by banks' total gross income, IT Spending/Non-interest expense is total IT spending scaled by non-interest expenses; IT spending/Net income is total IT spending scaled by total income minus the gross total expenses. The different categories of IT spending are the four categories of IT spending scaled by total IT spending.

	Mean	S.d.	p(25)	Median	p(75)
Total IT Spending (Million)	7.311	111.354	0.030	0.215	1.056
No. of IT Employees	133.434	872.102	7.000	21.578	56.400
Storage Amount(PB)	3.517	25.522	0.107	0.476	1.779
IT Spending/Revenue	0.031	0.155	0.003	0.010	0.023
IT Spending/Net income	0.597	18.475	0.018	0.051	0.135
IT Spending/Expenses	0.037	0.191	0.004	0.012	0.028
IT Spending/Non-interest Expenses	0.044	0.213	0.005	0.014	0.034
Communication/Total	0.092	0.117	0.028	0.052	0.105
Software/Total	0.334	0.161	0.220	0.321	0.474
Hardware/Total	0.171	0.119	0.063	0.158	0.235
Services/Total	0.327	0.137	0.243	0.323	0.417
Other/Total	0.056	0.099	0.008	0.014	0.062

Table 3. C&I Loans and Banks' IT Spending

This table presents the results of regression of banks' C&I loan on the four major categories of banks' IT spending and a vector of control variables at bank-year level. The sample period is 2010 to 2019.

$$\frac{\text{Type S IT spending}}{\text{Revenue}}_{i,10-19} = \alpha + \beta \frac{\text{C\&I Loan}}{\text{Total loan}}_{i,10-19} + \gamma X + \epsilon_i$$

C&I Loan/Total Loan is commercial and industrial loan of bank i scaled by total loan between 2010-2019, Software/Rev is software spending scaled by total revenue, Communication/Rev is communication spending scaled by total revenue, Hardware/Rev is Hardware spending scaled by total Revenue, Services/Rev. Control variables include net income scaled by total assets, deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets. Both the left-hand side and the right-hand side variables are taken the average across 2010-2019 within bank i. Fixed effects include Bank size, and banks' headquarter state fixed effects. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Software/Revenue	Communication/Revenue	Hardware/Revenue	Services/Revenue
	(1)	(2)	(3)	(4)
C& I loans/Total loan	0.031	0.050**	0.049**	0.043*
	(0.025)	(0.024)	(0.024)	(0.025)
Net income/Total Assets	-0.142***	-0.217***	-0.242***	-0.107***
	(0.028)	(0.028)	(0.028)	(0.029)
Deposits/Assets	-0.013	0.028	0.032	-0.008
	(0.031)	(0.030)	(0.030)	(0.031)
Revenue per Employee	-0.267***	-0.347***	-0.301***	-0.298***
	(0.035)	(0.034)	(0.034)	(0.035)
Salaries/Assets	-0.018	-0.132***	-0.099***	-0.034
	(0.026)	(0.025)	(0.025)	(0.026)
Equity/Assets	0.070**	0.051*	0.046*	0.071***
	(0.028)	(0.027)	(0.027)	(0.028)
Size FE	Y	Y	Y	Y
State FE	Y	Y	Y	Y
AdR-squared	0.098	0.162	0.150	0.110
N	1798	1798	1798	1798

Table 4. Loan Specialization and Banks' IT Spending

This table presents the results of regression of banks' C&I loan on the four major categories of banks' IT spending and a vector of control variables at bank-year level. The sample period is 2010 to 2019.

$$\frac{\text{Type S IT spending}}{\text{Revenue}}_{i,10-19} = \alpha + \beta \frac{\text{Type L Loan}}{\text{Total loan}}_{i,10-19} + \gamma X + \epsilon_i$$

Type L Loan/Total Loan is the average of a specific type of loan scaled by total loan, among them, Personal loan/Total Loan is the sum of personal loan and real estate loan to 1-4 family units scaled by total loan, Agriculture/Total loan is the agricultural loan scaled by total loan. CRA/Total loan is the sum of small business loans reported in CRA scaled by total loan, "Other C&I/Total loan" is the total C&I loan minus small business loans reported in CRA, scaled by total loan. "Mortgage refinance" is the total amount of mortgage refinance reported in HMDA scaled by the bank's total loan, "Other personal loans" is the deduction of "Mortgage refinance" from "Personal and mortgage loans". All of the loan profile variables are calculated as the average of the loan profile of a bank between 2010 and 2019. %Lead bank is the frequency of a banks' showing up as a lead bank in the syndicated loan market as a share of total number of syndicated loans lent out. %Refinance is the frequency of refinance as a percent of total number of mortgage issuance that are reported in HMDA. Software/Rev is software spending scaled by total revenue, Communication/Rev is communication spending scaled by total revenue, Hardware/Rev is Hardware spending scaled by total Revenue, Services/Rev. Control variables include net income scaled by total assets, deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets. Fixed effects include Bank size, and banks' headquarter state fixed effects. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Software/Revenue	Communication/Revenue	Hardware/Revenue	Services/Revenue
	(1)	(2)	(3)	(4)
C& I loans/total loan	0.031	0.050**	0.049**	0.043*
	(0.025)	(0.024)	(0.024)	(0.025)
CRA/Total loan	-0.150***	0.113***	0.063**	0.039
	(0.029)	(0.028)	(0.029)	(0.029)
Other C&I/Total loan	0.050**	0.036	0.041*	0.039
	(0.025)	(0.024)	(0.024)	(0.025)
% Lead bank/Total Syndicate	-0.612*	1.759***	1.393***	1.083***
	(0.333)	(0.295)	(0.278)	(0.262)
Personal loan/Total loan	0.045*	0.033	-0.014	0.025
	(0.027)	(0.026)	(0.023)	(0.023)
Mortgage refinance/Total loan	0.093***	-0.032	0.033	0.027
	(0.033)	(0.034)	(0.035)	(0.029)
Other personal loans/Total loan	-0.028	0.039	0.019	0.011
	(0.026)	(0.028)	(0.035)	(0.026)
% Refinance/Total Mortgage	0.081***	-0.002	0.041*	0.055**
	(0.024)	(0.024)	(0.024)	(0.023)
Agricultural loans/Total loan	0.026	0.073**	0.048	0.043
	(0.031)	(0.030)	(0.030)	(0.031)

Table 5. Soft Information and Banks' IT Spending

This table presents the results of 2SLS and OLS discussed in Section 5.1. The first three columns show the results for the following specification:

$$\Delta \ln(\text{CRA})_{i,c,post} = \mu_i + \mu_1 \ln(1 + \text{Qualified Small Buzs})_{c,pre} + \mu_2 X_{i,c} + \epsilon_{i,c}$$
$$\Delta \ln(\text{IT})_{i,c,post} = \alpha_i + \beta \Delta \widehat{\ln(\text{CRA})}_{i,c,post} + \gamma X_{i,c} + \epsilon_{i,c}$$

The last two columns show the following OLS specification:

$$\Delta \ln(\text{IT})_{i,c,post} = \quad \alpha_i + \beta \times \Delta \ln(\text{CRA})_{i,c,post} + \mu_c + \gamma X_{i,c} + \epsilon_{i,c}$$

$\Delta\ln\ (\text{CRA})_{i,c,post}$ is the change in average natural log of small business loans reported in CRA of bank i at county c in year during 2014-2017 compared with the 2010-2013, Software/Revenue is software spending scaled by total revenue, Communication/Revenue is communication spending scaled by total expenses, Hardware/Revenue is Hardware spending scaled by total expenses, Services/Revenue. The four IT spending scaled by revenue is at bank-county-year level. The control variable "Revenue per employee" is at bank-county level. County level control variables include the labor force, population growth rate, and total number of establishments. Fixed effects include bank fixed effects. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	2SLS			OLS	
	Δ CRA	Δ Software	Δ Communication	Δ Software	Δ Communication
	(1)	(2)	(3)	(4)	(5)
ln(Qualified Small Busi)	0.171***				
	(0.023)				
$\Delta\widehat{\ln(\text{CRA})}$		0.018	0.070***		
		(0.017)	(0.017)		
Δln(CRA)				0.003	0.014*
				(0.008)	(0.008)
Revenue per Employee	0.002	0.186***	0.188***	0.186***	0.189***
	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
Bank FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
F-statistics	20.23	53.43	98.66	53.31	97.07
AdR-squared	0.431	0.157	0.147	0.157	0.146
N	21202	21200	21195	21200	21195

Table 6. Hard Information and Banks' IT Spending

This table presents the results of regressions discussed in Section 5.2.
The first three columns show the results for the 2SLS specification below:

$$\ln(\text{Refinance})_{i,c} = \mu_i + \mu_1 \text{Payments gap}_c + \mu_2 X_{i,c,t} + \epsilon_{i,c,t}$$
$$\left(\frac{\text{Type S IT Spending}}{\text{Revenue}}\right)_{i,c,t} = \alpha_i + \beta \ln(\widehat{\text{Refinance}})_{i,c} + \gamma X_{i,c,t} + \epsilon_{i,c,t}$$

The last two columns show the results of OLS specification below:

$$\frac{\text{Type S IT spending}}{\text{Revenue}}_{i,c,t} = \alpha_i + \mu_c + \ln(\text{Refinance})_{i,c,t} + \pi_t + \beta + \gamma X_{i,c,t} + \epsilon_{i,c,t}$$

ln $(\text{Refinance})_{i,c,t}$ is the amount of mortgage refinance loan issued by bank i in county c in year t. Payments gap is the hypothetical amount of interest payments that could be saved due to the interest rate gap, if local households choose to refinance their mortgages during the year of 2011 and 2015. Software/Revenue is software spending scaled by total revenue, Communication/Revenue is communication spending scaled by total expenses. Control variables include net income scaled by total assets, deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets, control variables are at bank-year level. Fixed effects include bank fixed effects, year fixed effects and county fixed effects. Standard errors are clustered at county and bank level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	2SLS			OLS	
	ln (Refinance)	Software/Revenue	Communication/Revenue	Software/Revenue	Communication/Revenue
	(1)	(2)	(3)	(4)	(5)
Payment gap	0.863***				
	(0.037)				
ln(Refinance)				0.016***	0.007*
				(0.003)	(0.003)
$\ln(\widehat{\text{Refinance}})$		0.067**	0.037		
		(0.026)	(0.025)		
Revenue per Employee	-0.329***	-0.334***	-0.329***	-0.332***	-0.328**
	(0.004)	(0.004)	(0.004)	(0.046)	(0.078)
Net income/Assets	0.009	0.002	0.009	-0.000	0.008
	(0.009)	(0.0092)	(0.009)	(0.021)	(0.019)
Equity/Assets	-0.028**	-0.014	-0.028**	-0.014	-0.028
	(0.011)	(0.012)	(0.012)	(0.043)	(0.022)
Deposits/Assets	0.063***	0.153***	0.063***	0.141*	0.056
	(0.016)	(0.017)	(0.016)	(0.064)	(0.034)
Bank FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
F Statistics	2408.16				
AdR-squared	0.018	0.008	0.018	0.438	0.450
N	63189	63159	63189	63159	63189

Table 7. IT Spending and IT Employment and Availability of Potential IT Employees

This table presents the evidence of identification of association between banks' IT spending and IT employment during the mortgage refinancing boom period. The regression equation is as follows

$$\Delta\text{IT Emp/Total Emp}_{i,c,15-19\rightarrow 10-14} = \alpha_i + \gamma \cdot \text{Land-grant college availability} + \mu X + \epsilon_{i,c}$$

$$\Delta\text{Software}/\Delta\text{Communication/Revenue} = \alpha_i + \beta \cdot \Delta\text{ IT }\widehat{\text{Emp/Total}}\text{ emp}_{i,c} + \phi X + \epsilon_{i,c}$$

Column (1) shows the results of the first stage and column (2) and (3) shows the results of the second stage. The control variable "Revenue per employee" is at bank-county level. Bank fixed effects are included. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A

	Δ IT emp/Total emp	Δ Software/Revenue	Δ Communication/Revenue
	(1)	(2)	(3)
$\mathbb{1}$(Land grant college)	0.058**		
	(0.028)		
Δ IT emp/Total emp		-0.045**	-0.024
		(0.018)	(0.015)
Revenue per Employee	0.017**	0.171***	0.279***
	(0.008)	(0.019)	(0.016)
Bank FE	Y	Y	Y
F-statistics	1027.368	30.178	114.349
AdR-squared	0.298	-0.220	-0.195
N	20035	20035	20035

Panel B

	Δ IT emp/Total emp	Δ Software/Revenue	Δ Communication/Revenue
	(1)	(2)	(3)
ln(min distance)	-0.021**		
	(0.009)		
Δ IT emp/Total emp		-0.044**	-0.024
		(0.018)	(0.015)
Revenue per Employee	0.015*	0.175***	0.284***
	(0.008)	(0.019)	(0.016)
Bank FE	Y	Y	Y
Controls	Y	Y	Y
F-statistics	501.784	15.108	57.833
AdR-squared	0.296	-0.223	-0.197
N	19588	19588	19588

Appendix

Figure A1. Total Asset of Banks in Sample

This figure shows the sum of total asset size of all banks in our sample from 2010 to 2019 U.S. The red dashed line is the sum of call commercial banks' asset size in U.S., data source is Board of Governors of the Federal Reserve System (US), Total Assets, All Commercial Banks [TLAACBW027SBOG]. The red solid line is the sum of total asset sizes of banks in our sample. The black solid line is the sample bank size out as a share of total nation-wide banks' total asset size.

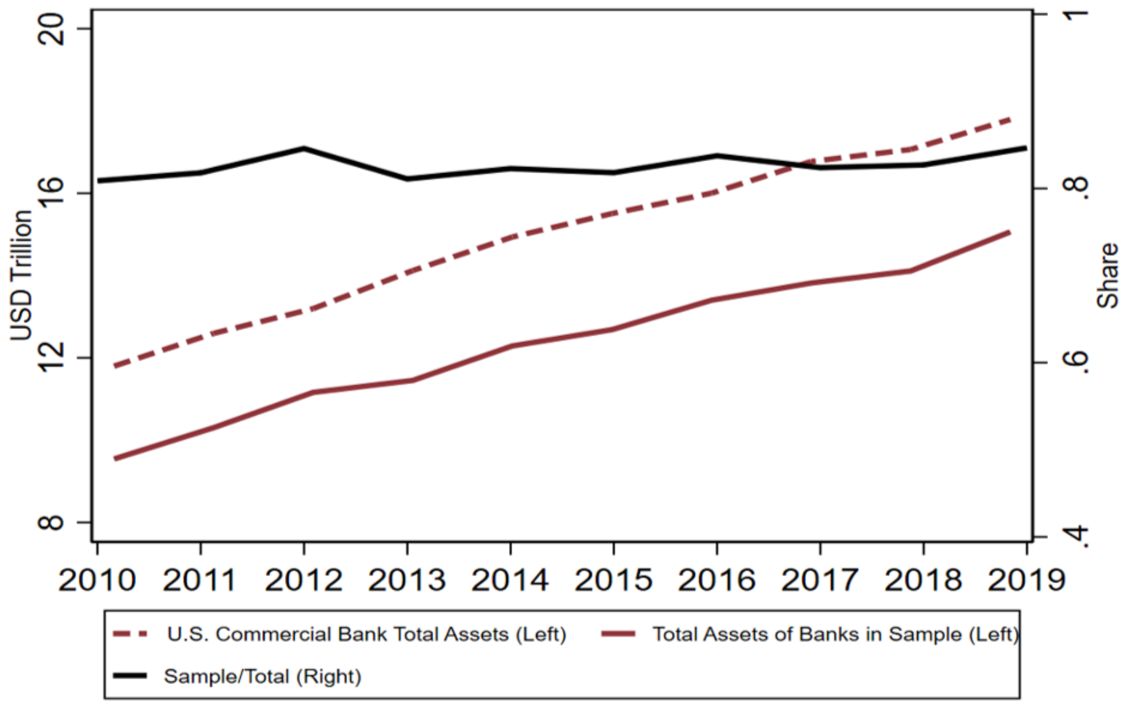


Figure A2. “Low Mortgage Rate Episode”

This figure shows the time-series of aggregate mortgage interest rate and the Federal Funds Rates. ”MORTGAGE30US” is the 30-Year Fixed Rate Mortgage Average in the United States from Freddie Mac. ”FEDFUNDS” is the effective Federal Funds Rate by Board of Governors of the Federal Reserve System.

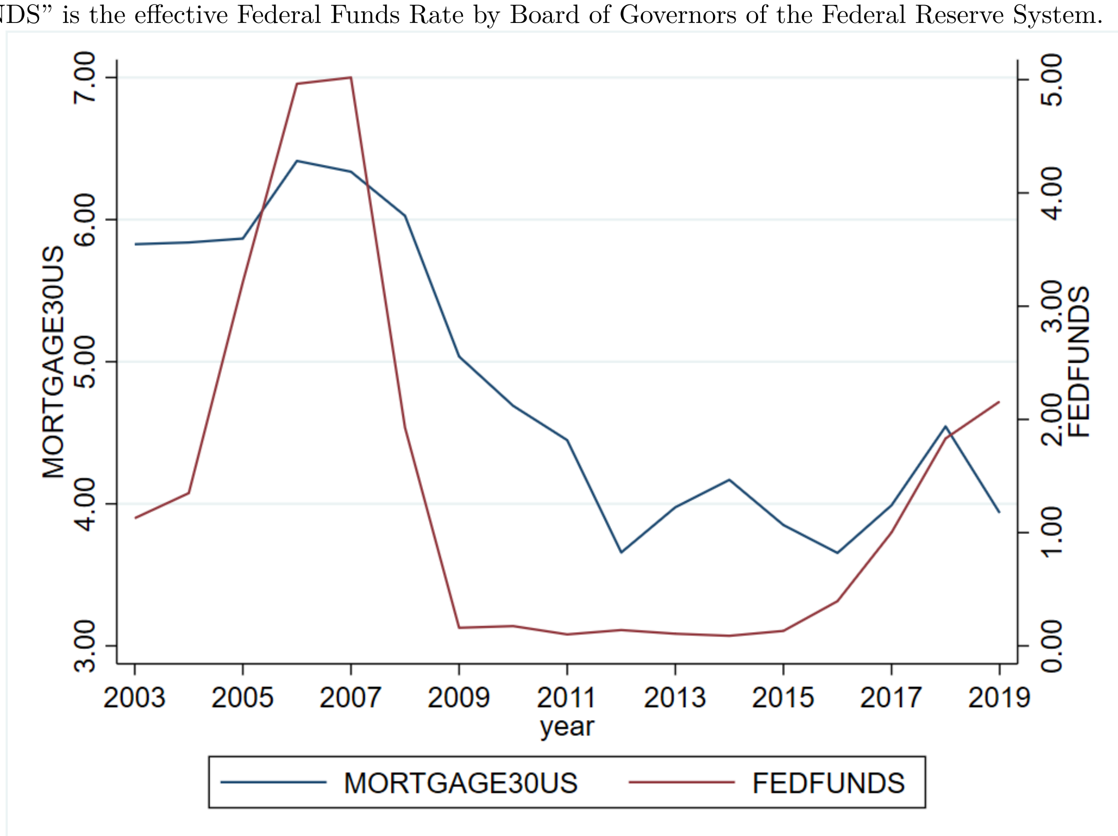


Figure A3. McKinsey (2012) "Breakthrough IT Banking"

Business Technology Office

Breakthrough IT banking

Some Asian banks achieve superior returns despite relatively low IT expenditures. What's their secret?

Sai Gopalan, Gaurav Jain, Gaurav Kalani, and Jessica Tan

Banks have long relied on technology to introduce products such as online banking, ATMs, and mobile payments, and to improve back-office efficiency. But that reliance comes with a price. Globally, the banking sector spends an average of 4.7 percent to 9.4 percent of operating income on IT, while other sectors spend less: insurance companies and airlines, for example, spend 3.3 percent and 2.6 percent of income, respectively.

Our Asian Banking IT Benchmarking Study[1] finds, however, that a bank's high IT expenditures do not always correlate with superior performance. Some banks with large IT budgets often have trouble leveraging investments to generate commensurately high revenue growth and operational efficiency. Survey data show that 66 percent of banks with higher-than-average IT spending relative to income generated lackluster results, with revenue growth 0.4 percentage points lower than the industry standard and a cost-income (C/I) ratio 2.5 percentage points higher.

By contrast, 23 percent of the 44 banks surveyed outperformed the market on both revenue growth (up 10.9 percentage points) and C/I ratio (down 4.6 percentage points) while spending 29 percent less on IT than other banks in our study. These outperforming banks are more likely to view IT as a strategic enabler, and their investments mirror this outlook. Outperformers direct a higher share of spending toward technologies designed to create new business value and a lower share of spending on support operations, such as finance and human resources. These banks are also more likely than the lower performers to promote efficiency through a consolidated IT footprint as well as formal vendor- and demand-management practices.

The common denominator linking high-performing Asian banks is a commitment to strong governance and spending alignment with the needs of the business. This finding supports our experience with bank clients in Europe and the Americas, and prompted us

[1] The 2010 biennial McKinsey Asian Banking IT Benchmarking survey comprised 44 banks across 11 Asia-Pacific countries, with the results tracked against prior year benchmarks from 2006 onward.

Figure A4. Definition of Different Types of IT Spending

- ***COMM_BUDGET***

The modeled IT budget for communication services at this site.
It is defined as the network equipment that companies operate to support their communications needs.
It includes:

  - routers
  - carrier line equipment
  - fiber optic equipment
  - switches
  - private branch exchanges (PBXes)
  - radio and TV transmitters
  - Wi-Fi transmitters
  - desktop telephone sets; wide-area network (WAN) and local-area network (LAN) equipment
  - videoconferencing and telepresence equipment
  - cable boxes
  - other network equipment.
  - end-client mobile devices like cell phones/iPhones that are bought by individuals

(a) Figure A

- ***SOFTWARE_BUDGET***

The modeled IT budget for software at this site.
It is defined as software from third parties, whether that software is packaged or semipackaged software delivered on CD and installed within the company, hosted by a third party, offered on a SaaS basis from a multitenant shared-instance server accessible by a browser, or custom-created for a company by third-party contractors or consultants.
It includes:

  - license, maintenance, subscriptions and software vendor-provided services revenues for all categories of middleware software (including storage management systems, database management systems, IT management systems, security software, application servers and application development software)
  - application software such as :
    - desktop applications
    - information management software (like business intelligence and enterprise content management)
    - process applications (like ERP, CRM, SCM or PLM)
    - ePurchasing software
    - risk and payment management software

    . We also include vertical industry applications (like banking management systems, security trading systems, insurance underwriting or claims management software, retail management software, or hospital information systems). Finally, we include computer operating systems software, even though that cost is often bundled
  - vertical industry applications (like banking management systems, security trading systems, insurance underwriting or claims management software, retail management software, hospital information systems)
  - computer operating systems software (even though that cost is often bundled)

(b) Figure B

- ***SERVICES_BUDGET***

The modeled IT budget for IT-related services at this site.
It is defined as project-based consulting or systems integration services that vendors provide to businesses and Governments, whether on or off-site.
It includes:

  - contractors, consulting services for IT strategy, security assessments and process change
  - systems integration
  - project services
  - mainframe outsourcing, desktop support outsourcing, distributed systems outsourcing, network outsourcing, application hosting, application management outsourcing and application testing. These applications are single-instance software deployments, generally owned rather than subscribed to, and thus are different from SaaS.
  - computer hardware support and maintenance services.

(c) Figure C

- ***HARDWARE_BUDGET***

The modeled IT budget for hardware at this site.
It includes the classic computer hardware that IT departments buy and support, regardless of whether the IT department itself operates that equipment (such as servers) or oversees the use of this equipment by employees (such as PCs):

  - PCs: personal computers (laptops, desktops, and tablets)
  - Servers/Mainframes
  - Peripherals: monitors, terminals, printers, keyboards, mice, USB devices, etc...
  - Storage: storage devices (NAS, DAS, tape)
  - Other hardware: hardware specific to the industry (point-of-sales equipment based on PCs, smart cards, embedded computer chips, etc…)

(d) Figure D

Table A1. Bank Characteristics and IT Spending

This table presents the results of regression of banks' IT spending structure between 2010 and 2019 on banks loan portfolio on balance sheet before the financial crisis. The regression specification is as follows:

$$\frac{\text{Type S IT spending}}{\text{Total}}_{i,2010-2019} = \alpha + \beta \frac{\text{Type l Loan}}{\text{Total loan}}_{i,2005-2009} + \gamma X + \epsilon_i$$

C&I loan/Total loan is commercial and industrial loan scaled by total loan; Personal loan/Total loan is personal loan and the real estate loan to 1-4 families scaled by total loan; agriculture loan/Total loan is agricultural loan scaled by total loan. All the three types of loans as a share of total loans are the bank-level average loan proportions from 2005 to 2009. IT spending profiles are defined as each type of IT spending scaled by total IT spending, and taking an average at the bank level between 2010 and 2019. Control variables include net income scaled by total assets, deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets, control variables are at bank-year level. Fixed effects include bank fixed effects, year fixed effects and county fixed effects. Standard errors are clustered at county and bank level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A

	$\frac{\text{Software}}{\text{Total}}_{10-19}$	$\frac{\text{Communication}}{\text{Total}}_{10-19}$	$\frac{\text{Hardware}}{\text{Total}}_{10-19}$	$\frac{\text{Services}}{\text{Total}}_{10-19}$
	(1)	(2)	(3)	(4)
C&I loan/Total loan(05-09)	-0.001	0.047***	0.041***	-0.011
	(0.022)	(0.015)	(0.015)	(0.016)
Net income/Total Assets	0.217	-0.166	-1.878***	2.017***
	(0.351)	(0.200)	(0.210)	(0.289)
Revenue per Employee	0.051**	0.041**	0.020	-0.026
	(0.025)	(0.017)	(0.014)	(0.028)
Equity/Assets	0.103	-0.008	-0.122*	0.087
	(0.100)	(0.071)	(0.071)	(0.085)
Salaries/Assets	1.304***	-0.334	0.215	0.580**
	(0.238)	(0.331)	(0.616)	(0.268)
Deposits/Assets	-0.044	0.018	0.026	-0.037
	(0.053)	(0.029)	(0.029)	(0.036)
AdR-squared	0.199	0.161	0.110	0.220
N	1649	1649	1649	1649

Panel B

	(1)	(2)	(3)	(4)
Personal loans/Total loan(05-09)	0.052***	-0.058***	-0.038***	-0.010
	(0.014)	(0.011)	(0.009)	(0.009)
Net income/Total Assets	0.382	-0.335*	-1.985***	1.981***
	(0.346)	(0.201)	(0.213)	(0.294)
Revenue per Employee	0.058**	0.041***	0.021	-0.030
	(0.027)	(0.015)	(0.013)	(0.027)
Equity/Assets	0.086	0.006	-0.114	0.092
	(0.101)	(0.071)	(0.071)	(0.085)
Salaries/Assets	1.244***	-0.269	0.257	0.592**
	(0.226)	(0.306)	(0.599)	(0.266)
Deposits/Assets	-0.043	0.023	0.031	-0.038
	(0.053)	(0.029)	(0.029)	(0.036)
AdR-squared	0.205	0.172	0.114	0.220
N	1649	1649	1649	1649

Panel C

	(1)	(2)	(3)	(4)
Agriculture loan/Total loan(05-09)	-0.082***	0.057***	0.028**	0.025**
	(0.015)	(0.015)	(0.013)	(0.011)
Net income/Total Assets	0.441	-0.307	-1.942***	1.945***
	(0.353)	(0.203)	(0.217)	(0.290)
Revenue per Employee	0.050**	0.049**	0.026*	-0.027
	(0.025)	(0.019)	(0.015)	(0.028)
Equity/Assets	0.079	0.003	-0.118*	0.096
	(0.100)	(0.071)	(0.071)	(0.085)
Salaries/Assets	1.211***	-0.271	0.245	0.609**
	(0.213)	(0.298)	(0.601)	(0.259)
Deposits/Assets	-0.055	0.031	0.036	-0.035
	(0.052)	(0.029)	(0.029)	(0.036)
AdR-squared	0.208	0.165	0.109	0.221
N	1649	1649	1649	1649

Table A2. Summary Statistics of Banks' IT Spending by Bank Size Group

This table presents the summary statistics of banks' IT spending by banks' size groups. Banks in the sample are split into five groups. Total IT Spending is the sum of all types of IT spending in millions of dollars. No. of IT employees is the total amount of IT-related employees. IT Spending/Income is total IT Spending scaled by banks' total income, IT Spending/Non-interest expense is total IT spending scaled by non-interest expenses; IT spending/Net income is total IT spending scaled by total income minus the gross total expenses. The different categories of IT spending are the four categories of IT spending scaled by total IT spending.

	Mean	S.d.	Median
< $100 Million			
IT Spending/Revenue	0.015	0.048	0.005
IT Spending/Expenses	0.019	0.075	0.007
Communication/Total	0.159	0.176	0.086
Software/Total	0.343	0.132	0.341
Services/Total	0.330	0.138	0.340
Hardware/Total	0.206	0.133	0.203
PC/Total	0.102	0.132	0.075
Server/Total	0.100	0.127	0.066
Terminal/Total	0.023	0.081	0.004
Printer/Total	0.022	0.081	0.003
Storage/Total	0.092	0.135	0.040
Other/Total	0.098	0.137	0.037

	Mean	S.d.	Median
$100 Million-$1 Billion			
IT Spending/Revenue	0.028	0.140	0.009
IT Spending/Expenses	0.040	0.200	0.014
Communication/Total	0.090	0.109	0.052
Software/Total	0.370	0.155	0.348
Services/Total	0.308	0.124	0.316
Hardware/Total	0.167	0.115	0.158
PC/Total	0.066	0.090	0.053
Server/Total	0.070	0.087	0.052
Terminal/Total	0.012	0.047	0.004
Printer/Total	0.011	0.047	0.003
Storage/Total	0.051	0.091	0.022
Other/Total	0.056	0.097	0.014

	Mean	S.d.	Median
$1 Billion-$10 Billion			
IT Spending/Revenue	0.043	0.193	0.014
IT Spending/Expenses	0.062	0.262	0.021
Communication/Total	0.064	0.078	0.042
Software/Total	0.272	0.166	0.231
Services/Total	0.361	0.152	0.336
Hardware/Total	0.165	0.117	0.140
PC/Total	0.056	0.064	0.043
Server/Total	0.065	0.063	0.050
Terminal/Total	0.007	0.021	0.004
Printer/Total	0.007	0.022	0.003
Storage/Total	0.033	0.061	0.017
Other/Total	0.036	0.072	0.012

	Mean	S.d.	Median
$10 Billion-$250 Billion			
IT Spending/Revenue	0.045	0.249	0.012
IT Spending/Expenses	0.067	0.310	0.019
Communication/Total	0.055	0.052	0.042
Software/Total	0.283	0.161	0.233
Hardware/Total	0.147	0.105	0.108
Services/Total	0.335	0.137	0.293
PC/Total	0.047	0.041	0.029
Server/Total	0.057	0.041	0.038
Terminal/Total	0.006	0.009	0.004
Printer/Total	0.005	0.010	0.003
Storage/Total	0.027	0.036	0.011
Other/Total	0.032	0.057	0.010

	Mean	S.d.	Median
> $250 Billion			
IT Spending/Revenue	0.019	0.049	0.005
IT Spending/Expenses	0.031	0.075	0.008
Communication/Total	0.046	0.041	0.031
Software/Total	0.268	0.137	0.228
Services/Total	0.357	0.149	0.328
Hardware/Total	0.158	0.103	0.138
PC/Total	0.051	0.043	0.039
Server/Total	0.062	0.044	0.050
Terminal/Total	0.007	0.011	0.004
Printer/Total	0.006	0.012	0.003
Storage/Total	0.031	0.039	0.018
Other/Total	0.036	0.061	0.012

Table A3. Bank Size, Loan Information Nature and Banks' IT Spending

This table presents the results of regression of Banks' IT spending response when small business loans and mortgage refinance volume increases, interacting with bank size. This table focuses on software spending and communication spending. The left-hand side variables are software spending as a share of total revenue and communication spending as a share of total revenue respectively. The right-hand side variables are banks' small business loans and mortgage refinance respectively, interacting with banks' size groups. "Small" is defined as banks with average asset size less than $100 million between 2010-2019, "Medium" is defined as banks with average asset size $100 million-$10 billion between 2010-2019, "Large" is defined as banks with average asset size greater than 10 $ Billion between 2010-2019. Control variables include net income scaled by total assets,deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets, control variables are at bank-year level. Fixed effects include bank fixed effects, year fixed effects and county fixed effects. Standard errors are clustered at county and bank level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Software/Revenue		Communication/Revenue	
	(1)	(2)	(3)	(4)
(Small) × ln(CRA)	-0.015		0.023	
	(0.045)		(0.046)	
(Medium) × ln(CRA)	-0.008		0.029***	
	(0.007)		(0.006)	
(Large) × ln(CRA)	0.015		0.031***	
	(0.012)		(0.011)	
(Small) × ln(Mortgage refinance)		-0.002		-0.006
		(0.006)		(0.006)
(Medium) × ln(Mortgage refinance)		0.016**		0.007
		(0.006)		(0.006)
(Large) × ln(Mortgage refinance)		0.034***		-0.046***
		(0.010)		(0.010)
Fixed effects	Bank, County, Year			
Bank Controls	Y	Y	Y	Y
AdR-squared	0.533	0.525	0.540	0.532
N	160214	156718	160259	156762

Table A4. Small Business Loan, Mortgage Refinance and Bank IT Spending: II

This table presents regression results of banks' new mortgage issuance on the four major categories of banks' IT spending and relevant control variables at bank-county-year level. The sample period is 2010 to 2019.

$$\frac{\text{Type S IT spending}}{\text{Revenue}}_{i,c,t} = \alpha_i + \mu_{c,t} + \beta \ln(\text{refinance})_{i,c,t} \text{ or } \ln(\text{CRA})_{i,c,t} + \gamma X + \epsilon_{i,c,t}$$

ln refinance$_{i,c,t}$ is the natural logarithm of newly mortgage refinance of bank i at county c in year t in reported in HMDA, ln CRA$_{i,c,t}$ is the natural logarith of small business loans issued by bank i in county c and in year t. Software(Communication)/Revenue is software (communication) spending scaled by total revenue, measured at bank-county-year level. Control variables include net income scaled by total assets, deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets, control variables are at bank-year level. Fixed effects include bank fixed effects, county × year. Standard errors are clustered at county and bank level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A

	Software/Revenue			Communication/Revenue		
	(1)	(2)	(3)	(4)	(5)	(6)
ln(refinance)	0.027***	0.035***	0.034***	-0.002	0.003	0.002
	(0.006)	(0.007)	(0.010)	(0.008)	(0.007)	(0.007)
Revenue per Employee		-0.213***	-0.225***		-0.228***	-0.236***
		(0.014)	(0.015)		(0.011)	(0.012)
Net income/Assets		0.004	0.004		0.028***	0.033**
		(0.011)	(0.012)		(0.010)	(0.014)
Equity/Assets		0.013	0.003		-0.007	-0.012
		(0.028)	(0.027)		(0.011)	(0.012)
Deposits/Assets		0.104	0.106*		0.022	0.024
		(0.070)	(0.060)		(0.029)	(0.023)
Salaries/Assets		-1.560	-1.382		-0.899	-0.800
		(1.064)	(1.089)		(1.281)	(1.349)
Fixed effects	Bank, **County**×**Year**					
Bank Controls	Y	Y	Y	Y	Y	Y
AdR-squared	0.449	0.477	0.487	0.468	0.496	0.501
N	179713	176486	159732	179759	176532	159778

Panel B

	Software/Revenue			Communication/Revenue		
	(1)	(2)	(3)	(4)	(5)	(6)
ln(CRA)	0.005	0.006*	0.006	0.014***	0.014***	0.014***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Revenue per Employee		-0.212***	-0.224***		-0.228***	-0.235***
		(0.014)	(0.015)		(0.011)	(0.012)
Net income/Assets		0.003	0.002		0.026**	0.028**
		(0.010)	(0.011)		(0.010)	(0.013)
Equity/Assets		0.011	0.002		-0.006	-0.010
		(0.028)	(0.027)		(0.011)	(0.012)
Deposits/Assets		0.097	0.101*		0.022	0.025
		(0.068)	(0.059)		(0.029)	(0.023)
Salaries/Assets		-0.702	-0.548		-0.394	-0.304
		(0.825)	(0.880)		(0.988)	(1.049)
Fixed effects	Bank, **County**×**Year**					
Bank Controls	Y	Y	Y	Y	Y	Y
AdR-squared	0.459	0.485	0.497	0.479	0.506	0.511
N	184314	181056	163775	184363	181105	163824

Table A5. IT Spending and IT Employment

This table presents the results of association between banks' IT investment and banks' employment, with a distinction between IT employees and non-IT employees. The regression equations are as follows:

$$\Delta \ln \text{ IT Emp or } \Delta \ln \text{Non-IT employees} = \beta \Delta \ln(\text{Software spending})_{i,c,t} \text{ or } \Delta \ln(\text{Communication spending})_{i,c,t} + \alpha_{i,t} + \mu_{c,t} + \gamma X + \epsilon_{i,c,t}$$

Δlog IT Emp and Δlog Non-IT Emp are the logarithm of IT related employees and Non-IT related employees respectively. Software/Revenue is software spending scaled by total revenue, Communication/Revenue is communication spending scaled by total revenue. The IT spending scaled by revenue is at bank-county-year level. Control variables include net income scaled by total assets, deposits scaled by total assets, revenue per employee, salaries scaled by total assets and equity scaled by total assets, control variables are at bank-year level. Fixed effects include bank-year fixed effects and county-year fixed effects. Standard errors are clustered at county and bank level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Δ ln IT Emp	Δ ln Non-IT Emp	Δ ln IT Emp	Δ ln Non-IT Emp
	(1)	(2)	(3)	(4)
Δ ln Software	-0.148***	-0.117***		
	(0.051)	(0.043)		
Δ ln Communication			0.043**	0.086***
			(0.022)	(0.022)
County×Year FE	Y	Y	Y	Y
Bank×Year FE	Y	Y	Y	Y
Control	Y	Y	Y	Y
AdR-squared	0.237	0.231	0.236	0.232
N	148617	148617	148617	148617