

Digital transformation - why do some significant banks fall behind?



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Abstract

This paper shows that larger banks and better capitalised banks invest more in computer software. These findings could reflect that larger banks can attain greater benefits from computer software and that better capitalised banks have more resources to make larger software investments. All the same, smaller and less capitalised banks will also have to make substantial software investments to maintain sustainable businesses, something that supervisors will need to point that out to these banks.

This document was provided by the Economic Governance Support Unit at the request of the ECON Committee.

This document was requested by the European Parliament's Committee on Economic and Monetary Affairs.

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Manuscript completed in June 2021
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CONTENTS

LIST OF ABBREVIATIONS	6
LIST OF FIGURES	7
LIST OF TABLES	7
EXECUTIVE SUMMARY	8
1. INTRODUCTION	9
2. DATA ON IT SPENDING AND CYBERATTACKS FROM THE ECB	11
3. AN ANALYSIS OF THE OWNERSHIP OF COMPUTER SOFTWARE BY SSM BANKS	13
4. CYBER RISK AS A SOURCE OF SYSTEMIC RISK AND THE NEED FOR MACROPRUDENTIAL SUPERVISION	19
5. CONCLUSION	20
REFERENCES	21
ANNEX	22

LIST OF ABBREVIATIONS

BHC	Bank Holding Company
EBA	European Banking Authority
ECB	European Central Bank
ESRB	European Systemic Risk Board
IAS	International Accounting Standard
ICT	Information and Communication Technology
IFRS	International Financial Reporting Standards
IT	Information Technology
ROA	Return on assets
SREP	Supervisory Review and Evaluation Process
SSM	Single Supervisory Mechanism

LIST OF FIGURES

Figure 1: Split of cyber incidents in 2019 and 2020 by type	11
Figure 2: Successful cyberattacks by institution versus ratios of IT expenses	12
Figure 3: Distribution of IT costs as a share of total operating income	12
Figure 4: Histogram of computer software over assets	14
Figure 5: Trend in computer software over assets of SSM banks	14
Figure 6: Bank types and computer software over assets	15
Figure 7: Scatterplots of computer software over assets with selected bank variables	15

LIST OF TABLES

Table 1: Computer software over assets at SSM banks and COVID-19	18
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EXECUTIVE SUMMARY

In recent years, banks have become increasingly digitalised, as they rely on information technology (IT) to deliver financial services to their customers and to automate internal processes. The digital transformation poses two main risks to the banking sector. First, banks that transform too slowly may be unable to compete effectively with more digitalised competitors, which implies that their business models are ultimately unsustainable. Second, a heavy reliance on IT introduces the risk of IT malfunctions, which can occur accidentally or as a result of malicious intent.

In its presentation of the Supervisory Review and Evaluation Process results for 2020, the European Central Bank notes that IT costs appear to be on the low side, with approximately one in five banks spending less than 3% of their total operating income on IT costs in the first three quarters of 2020. Furthermore, the lowest share is recorded by diversified lenders, universal and investment banks.

To shed more light on which banks fall behind in the digital transformation, this paper examines banks' ownership of computer software assets, which are recorded as an intangible asset on banks' balance sheets. Computer software assets include purchased software and internally developed software, thus measuring a bank's digital technology adoption and production. Our sample consists of 75 significant institutions during the period 2005-2020. Average computer software over assets increased from around 0.08% at the time of the Global Financial Crisis to a much higher level of around 0.2% during 2018-2020.

Empirically, we find that larger banks and better capitalised banks invest more in computer software after controlling for variation in bank business models and bank specialisation indices. These findings could reflect that larger banks can attain greater benefits from computer software and that better capitalised banks have more resources to make larger software investments. All the same, smaller and less capitalised banks will also have to make substantial software investments to maintain sustainable businesses, and supervisors need to point that out to these banks. If in the end smaller and less capitalised banks cannot make sufficient software investments, then they could consider merging with larger and better capitalised rivals in order to advance in the digital transformation.

1. INTRODUCTION

In recent years, banks have become increasingly digitalised, as they rely on information technology (IT) to deliver financial services to their customers and to automate internal processes. The digital transformation poses two main risks to the banking sector. First, banks that transform too slowly may be unable to compete effectively with more digitalised competitors, which implies that their business models are ultimately unsustainable. Second, a heavy reliance on IT introduces the risk of some IT malfunction, which can occur accidentally or because of malicious intent. In particular, cyberattacks can generate operational losses for the directly affected financial institutions. In addition, they can potentially trigger a systemic financial crisis if the effects of the cyberattack reverberate through the financial system (see European Systemic Risk Board (ESRB), 2020).

In its presentation of the Supervisory Review and Evaluation Process (SREP) results for 2020, the European Central Bank (ECB, 2021a, Chart 16) notes that IT costs appear to be on the low side, with approximately one in five banks spending less than 3% of their total operating income on IT costs in the first three quarters of 2020. Furthermore, the lowest share is recorded by diversified lenders, universal and investment banks.¹

To shed more light on which banks fall behind in the digital transformation, we examine banks' ownership of computer software assets, which are recorded as an intangible asset on banks' balance sheets. Computer software assets include purchased software and internally developed software, and thus measure a bank's digital technology adoption as well as production. Our sample consists of 75 Single Supervisory Mechanism (SSM) banks during the period 2005-2020. Average computer software over assets increased from around 0.08% at the time of the Global Financial Crisis to a much higher level of around 0.2% during 2018-2020.

Empirically, we find that larger banks and better capitalised banks invest more in computer software after controlling for variation in bank business models and bank specialisation indices. These findings could reflect that larger banks can attain greater benefits from computer software and that better capitalised banks have more resources to make larger software investments. All the same, also smaller and less capitalised banks will have to make substantial software investments to maintain sustainable businesses, and supervisors need to point that out to these banks. If in the end smaller and less capitalised banks cannot make sufficient software investments, then they could consider merging with larger and better capitalised rivals in order to advance in the digital transformation.

In 2017, the European Banking Authority (EBA, 2017) issued its 'Guidelines on the assessment of Information and Communication Technology (ICT) risk under the SREP', which provides a framework for assessing ICT risks at individual banks. Following these guidelines, the ECB together with National Competent Authorities developed an IT risk questionnaire to be completed by banks on an annual basis. Last year the ECB (2020a) published the results of a horizontal analysis of the answers to this questionnaire provided by significant institutions in the first quarter of 2019. This analysis reveals that the number of successful cyberattacks at the bank level is negatively correlated with the ratio of IT expenses to total budgeted expenses and with the ratio of IT innovation to IT expenses.² Thus, banks with low IT expenses, and especially IT innovation expenses, appear to be more vulnerable to successful

¹ In the pragmatic 2020 SREP, the ECB maintained the same SREP scores as in the previous year, and hence this observation did not affect 2020 SREP scores. The data provided on qualitative SREP recommendations (ECB, 2021a, Chart 10) is not granular enough to see whether the ECB issued any qualitative recommendations related to IT costs as part of the 2020 SREP.

² The definition of the ratio of IT innovation to IT expenses is not publicly available.

cyberattacks. For the current year, the ECB (2021b, Figure 1) identifies cybercrime and IT disruption as a significant risk and IT deficiencies as a vulnerability requiring supervisory attention.

Several recent studies have considered how IT investments affect banks' performance in a crisis setting.³ Using US data, Pierri and Timmer (2020) find that commercial banks with greater IT adoption, measured as more personal computers per employee, before the Great Financial Crisis experienced significantly lower non-performing loans when the crisis hit. Considering US banks at the time of the COVID-19 pandemic, Dadoukis, Fiaschetti and Fusi (2021) show that banks that are high IT adopters, indicated by a relatively high ratio of tech and communication expenses to total operating expenses, performed better in terms of market returns and lending during the early phase of the pandemic. Along similar lines, Kwan, Lin, Pursiainen and Tai (2021) demonstrate that US banks with a high IT capability, proxied by the adoption of technologies useful for remote or virtual work or other online communication, were better able to serve their customers during the pandemic, as indicated by larger increases in website traffic and greater volumes of lending and deposit taking. Together, these studies suggest that banks with higher IT investments can better weather a major economic shock, which provides a rationale for relatively high IT investments by banks.

In the remainder, section 2 discusses some data on the prevalence of cyberattacks and the correlation between IT spending and cyberattacks for significant institutions available from ECB publications. Section 3 provides evidence on the determinants of investments in computer software by significant institutions. Section 4 discusses cyber risk as a source of potential systemic risk and the need for macroprudential supervision to mitigate this risk. Section 5 concludes.

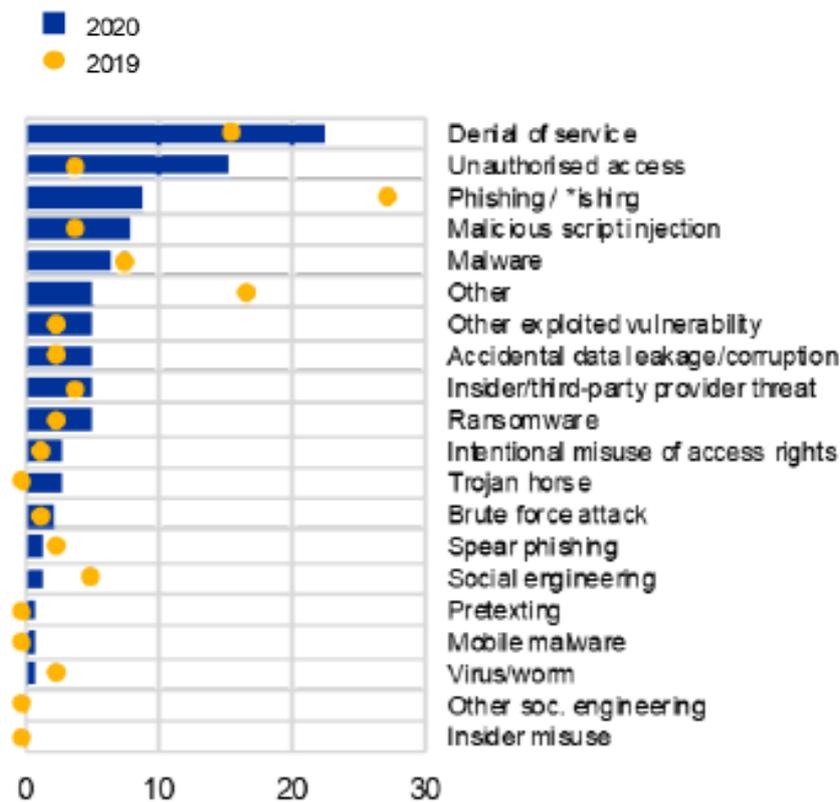
³ Beccalli (2007) finds that there is little relationship between banks' overall IT investments and improved profitability or efficiency for a sample of European banks over the period 1995-2000.

2. DATA ON IT SPENDING AND CYBERATTACKS FROM THE ECB

This section reviews some data on the prevalence of cyberattacks and the potential link between successful cyberattacks and IT spending available from ECB publications.

In 2017, the ECB adopted a cyber incident reporting framework that requires all banks that are supervised by the ECB to report significant cyber incidents on a confidential basis immediately after they have been detected. Figure 1 provides data on the types and numbers of cyber incidents reported by significant institutions in 2019 and 2020, showing an overall increase in 2020. The main types of cyber incident are denial of service attacks (many service requests directed at a financial institution to overwhelm its interface with customers), unauthorised access, and phishing (emails to bank employees or customers soliciting confidential access information).

Figure 1: Split of cyber incidents in 2019 and 2020 by type
(2019, 2020, percentages)



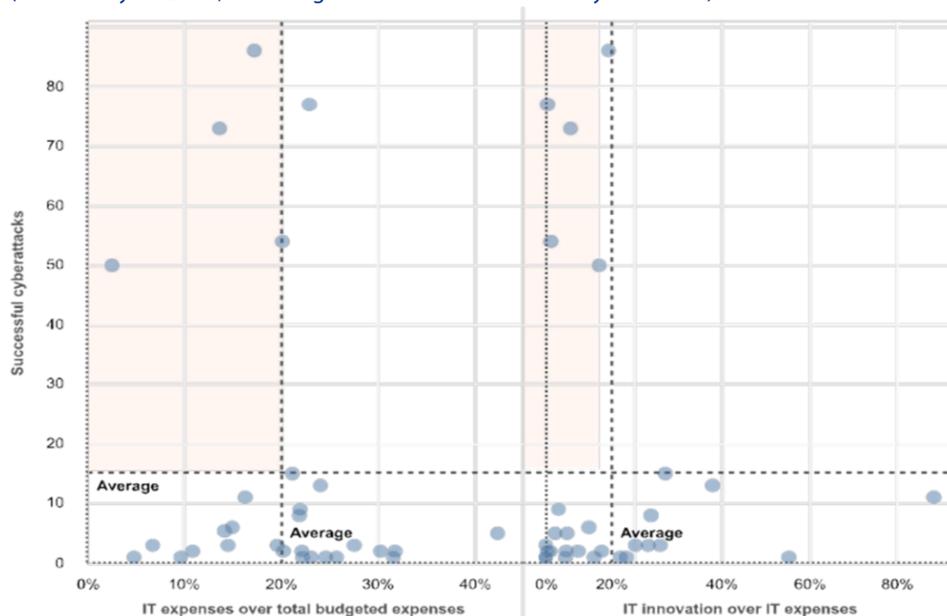
Reproduced from ECB (2021c, Chart 3.8). Insider misuse is international misuse of access rights by an insider.

Based on answers to the ECB’s IT risk questionnaire, Figure 2 shows negative relationships between the number of successful cyberattacks at the bank level and a bank’s ratio of IT expenses to total budgeted expenses as well as its ratio of IT innovation over IT expenses. Thus, higher IT expenses, and especially IT innovation expenses, appear to be useful to protect against cyberattacks.⁴

⁴ Note that the negative relationships are only apparent if we consider the full sample of banks, but not if we consider the subsamples where either IT expense ratio is below its average. This suggests IT spending needs to be above average to have a negative effect on the occurrence of successful cyberattacks.

Figure 2: Successful cyberattacks by institution versus ratios of IT expenses

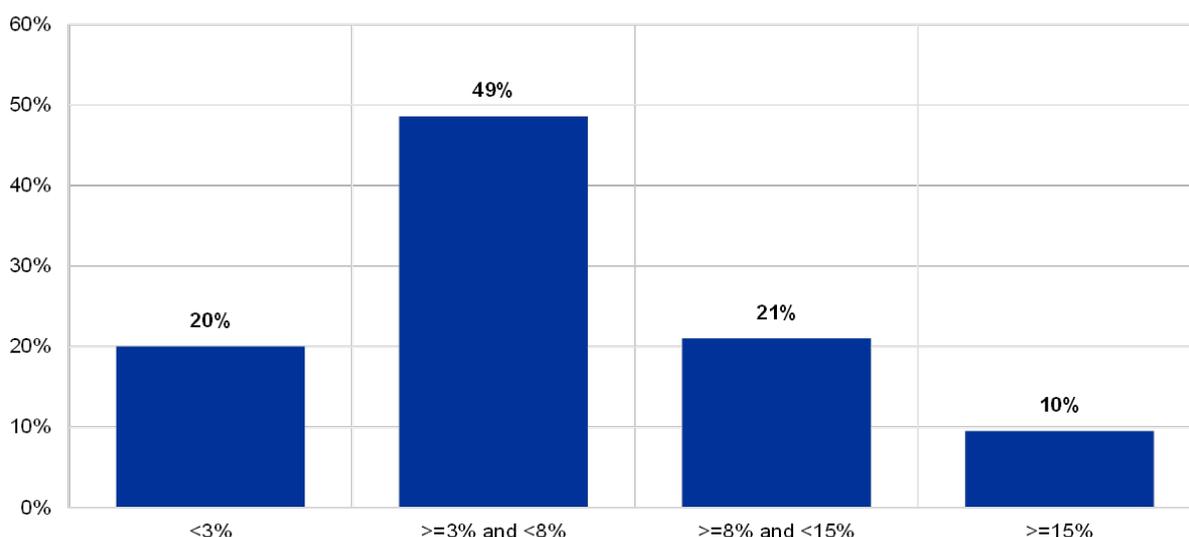
(reference year 2018; excluding banks with no successful cyberattacks)



Reproduced from ECB (2020a, Chart 12).

Banks tend to spend on IT rather unevenly. This is shown by Figure 3, which provides information on the distribution of IT costs as a share of total operating income for significant institutions, collected by the ECB in the course of the 2020 SREP. IT costs as a share of income are seen to be below 3% for the bottom quintile of significant institutions, while they are equal to or above 15% for the top decile. The revealed dispersion of IT costs potentially reflects that banks tend to implement different business models that require varying IT intensifies. Thus, a wide variation in banks’ IT costs by itself does not imply that some banks spend too little on IT. To inform on this issue, one needs to analyse the determinants of banks’ digitalisation efforts, including variation in their business models. We do this in the next section.

Figure 3: Distribution of IT costs as a share of total operating income



Reproduced from ECB (2021a, Chart 16) as based on supervisory data with reference date Q3 2020.

Y-axis indicates the % of significant institutions out of the full sample, which is made up of 105 significant institutions for which an SREP 2020 assessment was conducted and data are available.

3. AN ANALYSIS OF THE OWNERSHIP OF COMPUTER SOFTWARE BY SSM BANKS

The academic literature on IT adoption by banks tends to use technology expenses (and possibly communication expenses) to capture banks' reliance on IT.⁵ In this section, we instead focus on an alternative measure of IT adoption by banks: banks' ownership of computer software assets (relative to total assets).⁶ This measure captures banks' cumulative investment in computer software, which brings identifiable economic benefits. Empirically, we relate this measure of IT adoption to indices of a bank's size, its business model, and its capitalisation in order to see which banks appear to lag behind. Our sample consists of 75 SSM banks during the period 2005-2020. The data are taken from Moody's Analytics BankFocus.

European banks' accounting recognition of computer software assets should be a good measure of banks' digital technology adoption and production.⁷ According to International Accounting Standard (IAS) 38 as part of the International Financial Reporting Standards (IFRS), banks are required to recognise an intangible asset if it meets specific criteria. In particular, an intangible asset should be identifiable (i.e., it should be separable and transferable, and its costs should be measurable), and the bank should have control over the intangible asset so that it can create future economic benefits by increasing revenues or reducing costs.⁸ Intangible assets mostly have finite lives, and they generally are amortised over their lifetime. Computer software assets, recognised as intangible assets, include purchased software and internally developed software. Thus, computer software assets measure a bank's digital technology adoption and production, representing software used explicitly by banks to generate economic benefits.⁹

Computer software constitutes more than 60% of intangible assets for the group of SSM banks. The average value of computer software over total assets in the sample is 0.14%, whereas its median is 0.08%. In absolute terms, the value of computer software varies considerably, from 3.5 million euros at the 10th percentile of the distribution to 682 million euros at the 90th percentile. Figure 4 shows a histogram of computer software over assets for the SSM banks that shows a considerable dispersion.

⁵ See, for example, Dadoukis, Fiaschetti and Fusi (2021). Pierri and Timmer (2020) instead use a hardware measure of IT adoption (personal computers per employee), showing that this measure is correlated with the IT budget per employee and the adoption of cloud computing.

⁶ Data on computer software can be a complement to data on technology expenses. Data on technology expenses are not available from BankFocus for a sufficient number of banks. Hence, we are not able to compare these measures of IT adoption.

⁷ Sahut et al. (2011) show that IFRS provide better information regarding intangible assets for European listed companies in comparison to local GAAP.

⁸ See <https://www.iasplus.com/en/standards/ias/ias38> for details.

⁹ In contrast, operating systems as part of hardware are included in hardware costs.

Figure 4: Histogram of computer software over assets

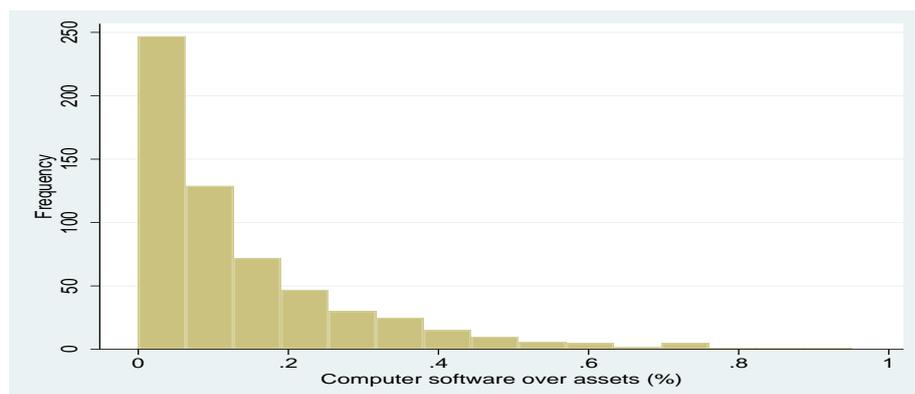
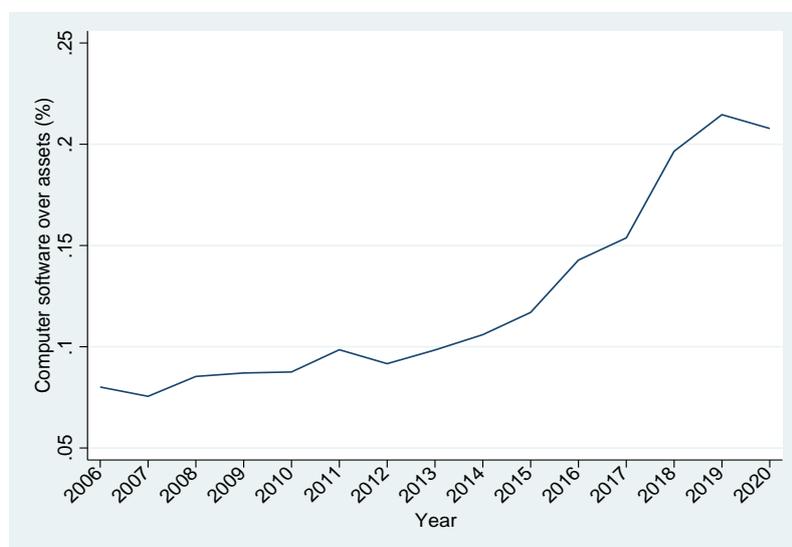


Figure 5 shows the time trend of software assets over total assets during the last 15 years. Average computer software over assets increased from around 0.08% during the Global Financial Crisis to a much higher level of around 0.2% during 2018-2020. In 2020, the average software assets over total assets declined slightly, probably on account of the pandemic.

Figure 5: Trend in computer software over assets of SSM banks

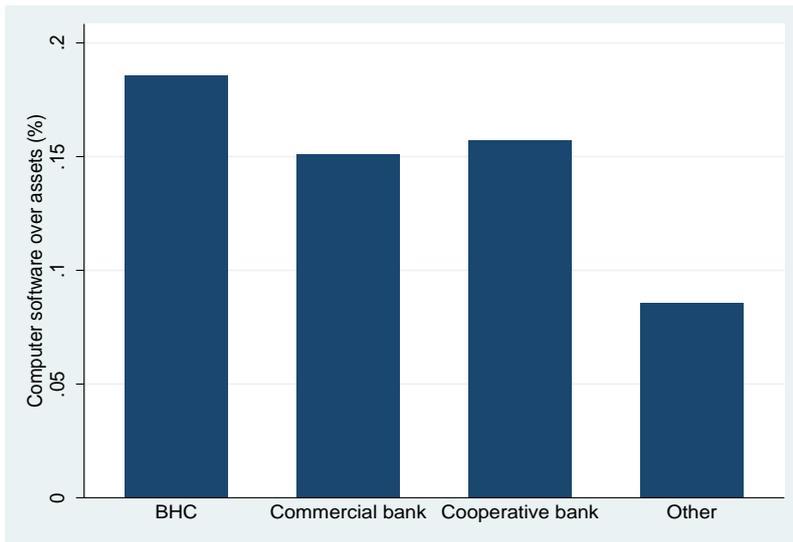


The figure shows average computer software over assets for banks with available data over time. The trend is similar in the case of asset-weighted averages or a balanced sample.

Using the information on bank specialisations from BankFocus, Figure 6 shows how computer software over assets varies for different types of bank. Bank holding companies, in particular, have average computer software over assets of 0.186%, whereas commercial banks and cooperative banks have averages of around 0.15%.¹⁰ Computer software over assets for the remainder category (including, for example, real estate and mortgage banks and savings banks) is 0.085%.

¹⁰ Similarly, financial holdings and credit institutions following the SSM definition have average computer software over assets of 0.24% and 0.12%, respectively.

Figure 6: Bank types and computer software over assets

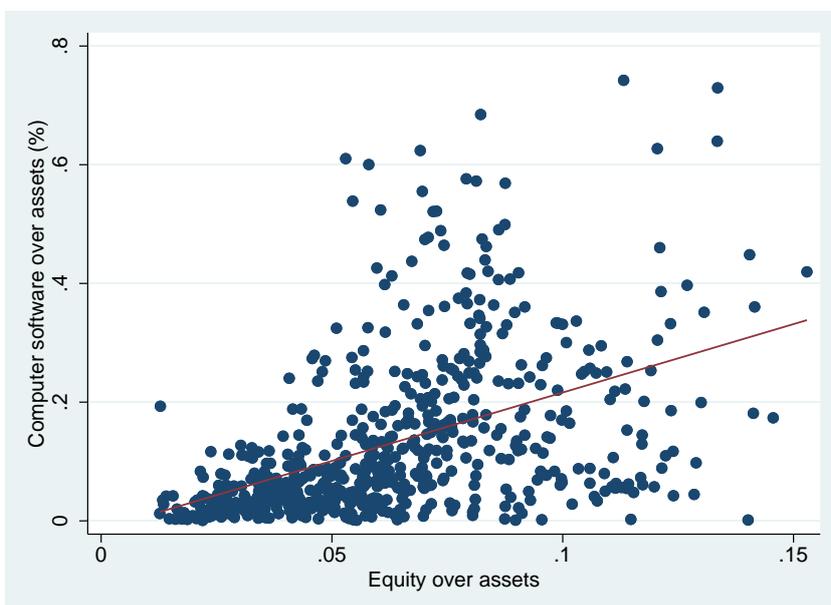


BHC is a bank holding company. The other category includes financial institutions such as real estate and mortgage banks, savings banks and specialised governmental credit institutions.

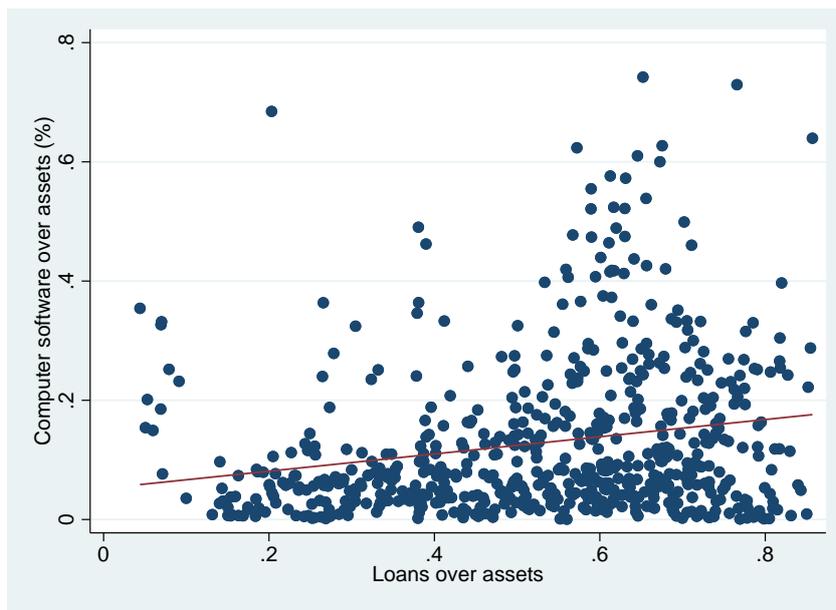
Before turning to the regression analysis, we present three simple scatterplots that relate values of computer software to assets to the ratios of equity to assets, loans to assets and customer deposits to assets, respectively (Figures 7A,B,C). The ratio of equity to asset is a measure of bank capitalisation, while the ratios of loans to asset and customer deposits to assets are indices of a bank’s business orientation. Computer software over assets is shown to be positively associated with equity over asset (Figure 7A). This association is potentially worrying, as it suggests that weakly capitalised banks are lagging behind in their IT adoption. Computer software over assets is further positively associated with loans over assets and customer deposits over assets (Figures 7B and 7C). Thus, banks with a greater focus on serving loan and deposit customers are shown to have progressed farther in their IT adoption as measured by computer software ownership, which probably reflects that these customers are increasingly served through digital platforms.

Figure 7: Scatterplots of computer software over assets with selected bank variables

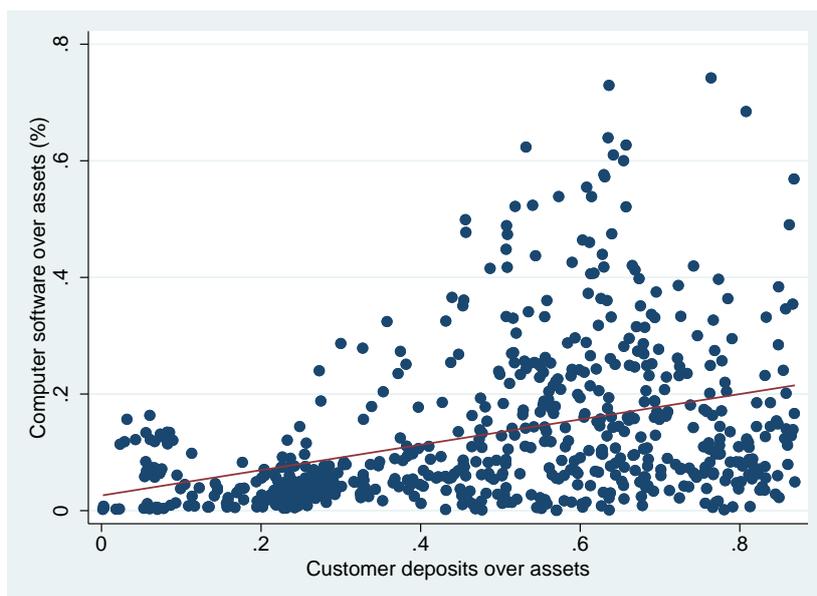
A: Equity over assets



B: Loans over assets



C: Customer deposits over assets



All variables in these scatterplots are trimmed at 1% and 99% to exclude outliers. Relationships without trimming are similar. A similar relationship also arises if equity over assets is replaced by tangible equity over tangible assets.

Next, we estimate the relationship between computer software over assets with various indices of bank size, business model and capitalisation.¹¹ We use the following specification:

$$\begin{aligned}
 \text{Computer software over assets}_{i,t} &= \alpha_{c*t} + \gamma_{spec} + \beta_1 \ln(\text{Total assets})_{i,t-1} + \beta_2 \text{Bank capitalisation}_{i,t-1} \\
 &+ \beta_3 \text{Loans over assets}_{i,t-1} + \beta_4 \text{Customer deposits over assets}_{i,t-1} + \beta_5 \text{ROA}_{i,t-1} \\
 &+ \varepsilon_{i,t}
 \end{aligned}$$

¹¹ See the Annex for variable definitions and summary statistics.

The dependent variable is *Computer software over assets* $_{i,t}$ for bank i in year t . Among the explanatory variables, $\ln(\text{Total assets})_{i,t-1}$ is the natural logarithm of total assets, which proxies for bank size. *Bank capitalisation* $_{i,t-1}$ is a bank capitalisation variable (either equity over assets, tangible equity over tangible assets, or the regulatory total capital ratio). *Loans over assets* $_{i,t-1}$ and *Customer deposits over assets* $_{i,t-1}$ capture a bank's orientation towards the traditional banking activities of lending and deposit taking. $ROA_{i,t-1}$ is a bank's return on assets, calculated as pre-tax profits divided by total assets.¹² We include bank specialisation fixed effects, γ_{spec} , that correspond to the banking categories represented in Figure 6.¹³ Finally, the econometric specification includes country-year fixed effects, α_{c*t} , capturing time varying differences at the country level, which could be significant as our sample period includes the Global Financial Crisis, the European sovereign debt crisis, and the COVID-19 pandemic.

Regression 1 in Table 1 includes equity over assets to capture bank capitalisation. In this regression, computer software over assets varies positively with the bank size variable, which implies that computer software rises more than proportionately with total assets as bank size increases. While this makes sense as larger banks can benefit more from any software purchase or development, this result potentially also spells trouble for smaller banks that apparently do not keep up in the digital transformation. Customer deposits over assets enters the regression positively, as taking deposits nowadays is an IT-intensive activity. Equity over assets is also positive in the regression. The estimated relation between software over assets and equity over assets is economically meaningful. Specifically, a one standard deviation increase in equity over assets (3.3%) implies an increase in software over assets of 0.05%, which is 34% of its standard deviation. From a supervisory perspective, it could be problematic that weakly capitalised banks invest less in computer software, as underinvestment in computer software by weakly capitalised banks could make their business models unsustainable.

In regression 2, we replace equity over assets with tangible equity over tangible assets (excluding intangible assets from both equity and assets) to prevent any mechanical relationship between computer software valuation and reported bank equity. The estimated coefficient for tangible equity over tangible assets is smaller than the coefficient for equity over assets in regression 1, but it is statistically significant. In regression 3, we replace equity over assets with the regulatory total capital ratio, which is not significantly correlated with computer software.

We also explore if any of the documented relationships changed during the COVID-19 period. In particular, we include interaction terms of all the explanatory variables with a dummy variable for the year 2020 in regressions 1-3, with the results reported as regressions 4-6. We find a stronger relationship between software over assets and bank size in 2020 than before. Furthermore, there was a more positive relationship between software over assets and loan over assets in 2020, perhaps because the pandemic forced additional lending activity to be conducted digitally.

In summary, we find that larger banks and better capitalised banks invest more in computer software after controlling for variation in bank business models and bank specialisation indices. These findings could reflect that (1) larger banks can attain greater benefits from computer software as any additional software can be applied to more voluminous banking activities for a given cost of the additional software and that (2) better capitalised banks have more resources to make larger software investments. All the same, also smaller and less capitalised banks will have to make substantial software investments to maintain sustainable businesses, and supervisors need to point that out to these banks. If, in the end, smaller and less capitalised banks cannot make sufficient software investments, then merging with larger and better capitalised rivals could offer a good way forward.

¹² The dependent variable is in percentages whereas all explanatory variables are in ratios. All explanatory variables are lagged by one year.

¹³ Bank specialisation fixed effects are not reported in Table 1, as they are not significant.

Table 1: Computer software over assets at SSM banks and COVID-19

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Computer software over assets (%)					
ln(Total assets)	0.041*** (0.013)	0.039*** (0.014)	0.038*** (0.014)	0.039*** (0.013)	0.037*** (0.013)	0.035*** (0.013)
Loans over assets	0.073 (0.064)	0.064 (0.064)	0.110 (0.073)	0.056 (0.060)	0.046 (0.061)	0.084 (0.067)
Customer deposits over assets	0.096** (0.043)	0.100** (0.043)	0.132** (0.054)	0.091** (0.042)	0.095** (0.041)	0.115** (0.053)
Equity over assets	1.513*** (0.529)			1.400*** (0.480)		
Tangible equity over tangible assets		1.357** (0.543)			1.268** (0.495)	
Total capital ratio			0.110 (0.081)			0.091 (0.078)
ROA	-1.008 (0.941)	-0.728 (0.918)	0.479 (0.898)	-0.859 (0.885)	-0.617 (0.860)	0.520 (0.818)
ln(Total assets)*Year2020				0.042** (0.018)	0.045** (0.020)	0.040* (0.024)
Loans over assets*Year2020				0.339** (0.159)	0.393** (0.161)	0.413** (0.197)
Customer deposits over assets*Year2020				-0.110 (0.101)	-0.100 (0.105)	0.054 (0.154)
Equity over assets*Year2020				1.331 (1.469)		
Tangible equity over tangible assets*Year2020					0.978 (1.479)	
Total capital ratio*Year2020						0.202 (0.404)
ROA*Year2020				-12.951 (8.933)	-12.400 (8.840)	-7.697 (8.077)
Observations	655	655	596	655	655	596
R-squared	0.625	0.616	0.621	0.634	0.625	0.629
Country*YearFE	Yes	Yes	Yes	Yes	Yes	Yes
Bank type FE	Yes	Yes	Yes	Yes	Yes	Yes

*, **, and *** denote significance at the 10%, 5%, and 1%.

4. CYBER RISK AS A SOURCE OF SYSTEMIC RISK AND THE NEED FOR MACROPRUDENTIAL SUPERVISION

According to the ESRB (2020, p. 2), cyber risk is characterised by three features that set it apart from other sources of operational risk: the speed of its propagation, the scale of its propagation, and the potential intent of threat actors. These cyber risk characteristics give rise to the possibility that a cyber incident, caused by, say, insufficient IT investment, evolves into a systemic financial crisis. The ESRB offers a conceptual model of how this can happen. For a system crisis to happen, there needs to be an amplification of the impact on the directly affected institutions towards the broader financial system. The initial shock, for instance, could be amplified, if it leads to a dysfunctional interbank money market or a bank run by depositors. In addition, amplification is more likely if the cyber incident erodes wider trust in the financial system. With sufficient amplification, banks can no longer provide credit, and a systemic financial crisis has materialised. The ESRB sketches the example of how a systemic financial crisis could evolve after the malicious destruction of account balance data at a large bank.¹⁴

As pointed out by Kashyap and Wetherit (2019), the appropriate regulatory and supervisory response to cyber risk needs to consider that cyber risk, unlike most other forms of operational risk, can entail strong negative externalities, potentially triggering a systemic crisis. These authors, in particular, identify the need for a macroprudential approach to cyber risk, recognising that similar cyber risks at individual banks can jointly create systemic risk. To identify potential common vulnerabilities, the authors recommend carrying out cyber stress tests. As a follow-up to such stress testing, supervisors could encourage firms to avoid common vulnerabilities, for instance by diversifying financial infrastructure or software choices.

The EBA (2019) has issued 'Guidelines on ICT security and risk management', which establish requirements for financial institutions regarding the management of ICT security and the mitigation of related risks. These guidelines are pertinent to individual banks, and thus microprudential rather than macroprudential.¹⁵ By default, the development of macroprudential policy to deal with cyber risk is left to the supervisor, or potentially to a consortium of internationally collaborating supervisors. In particular, the ECB could develop a macroprudential policy to deal with cyber risk at significant institutions and clarify to what extent it is at present implementing such a policy.¹⁶

¹⁴ Danielsson, Fouché, and Macrae (2016) are sceptical whether cyber risk can generate a systemic financial crisis. In particular, they argue that a cyberattack is unlikely to lead to a fall of confidence that is systemic and that only the largest sovereign states have sufficient resources to maliciously cause a systemic crisis.

¹⁵ Similarly, the approach to defining and assessing IT risks in ECB (2020a) is microprudential.

¹⁶ In recent articles on cyber risk in its supervision newsletter, the ECB (2019a, 2019b, 2020b) did not address the possibility of taking a macroprudential approach to cyber risk.

5. CONCLUSION

In its presentation of the Supervisory Review and Evaluation Process (SREP) results for 2020, the European Central Bank (ECB, 2021a, Chart 16) notes that IT costs appear to be on the low side, with approximately one in five banks spending less than 3% of their total operating income on IT costs in the first three quarters of 2020.

To shed light on which banks fall behind in the digital transformation, this paper examines banks' ownership of computer software assets, which are recorded as an intangible asset on banks' balance sheets. Computer software assets include purchased software and internally developed software, and thus measure a bank's digital technology adoption as well as production. Our sample consists of 75 Single Supervisory Mechanism (SSM) banks during the period 2005-2020.

Empirically, we find that larger banks and better capitalised banks invest more in computer software after controlling for variation in bank business models and bank specialisation indices. These findings could reflect that larger banks can attain greater benefits from computer software and that better capitalised banks have more resources to make larger software investments. All the same, also smaller and less capitalised banks will have to make substantial software investments to maintain sustainable businesses, and supervisors need to point that out to these banks. If, in the end, smaller and less capitalised banks cannot make sufficient software investments, then they could consider merging with larger and better capitalised rivals in order to advance in the digital transformation.

A macroprudential approach to cyber risk recognises that similar cyber risks at individual banks can jointly create systemic risk, for instance, if many banks are dependent on the same software. The development of macroprudential policy to deal with cyber risk appears to be the domain of the supervisor. Given this circumstance, the ECB could enunciate a macroprudential policy to deal with cyber risk at significant institutions and clarify to what extent it is currently implementing such a policy.

Potential questions:

Q1: Do you think that small banks are more at risk from cyber attacks (given they tend to invest less)?

Q2: When assessing cyber risk at significant institutions, does the ECB only take a microprudential approach or also a macroprudential approach?

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ANNEX

Table A1: Variable descriptions

Variable	Description
Computer software overassets (%)	Computer software net of accumulated amortisation and impairment divided by total assets in percentages
ln(Total assets)	Natural logarithm of total assets in thousands of euros
Loans over assets	Gross loans divided by total assets
Customer deposits overassets	Customer deposits divided by total assets
Equity over assets	Equity over total assets
Tangible equity over tangible assets	Equity minus intangible assets (including goodwill) divided by assets minus intangible assets
Total capital ratio	Regulatory capital divided by risk-weighted assets
ROA	Return on assets calculated as pre-tax profits divided by total assets

Table A2. Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Computer software overassets (%)	655	0.137	0.149	0	0.950
ln(Total assets)	655	18.185	1.665	13.583	21.635
Loans over assets	655	0.530	0.195	0.000	0.931
Customer deposits overassets	655	0.491	0.235	0.000	0.912
Equity over assets	655	0.064	0.033	-0.039	0.292
Tangible equity over tangible assets	655	0.060	0.032	-0.046	0.279
Total capital ratio	621	0.181	0.104	-0.050	1.112
ROA	655	0.003	0.014	-0.152	0.037

Negative values of bank capitalisation variables occurred for some banks during the European sovereign debt crisis. The regression results are not sensitive to excluding capitalizations below 0 or above 1.

This paper shows that larger banks and better capitalised banks invest more in computer software. These findings could reflect that larger banks can attain greater benefits from computer software and that better capitalised banks have more resources to make larger software investments. All the same, smaller and less capitalised banks will also have to make substantial software investments to maintain sustainable businesses, something that supervisors will need to point that out to these banks.

This document was provided by the Economic Governance Support Unit at the request of the ECON Committee.

PE 689.440

IP/A/ECON-BU/FWC/2020-003

Print ISBN 978-92-846-8316-1 | doi: 10.2861/82482 | QA-02-21-829-EN-C

PDF ISBN 978-92-846-8317-8 | doi: 10.2861/65571 | QA-02-21-829-EN-N