

Navigating the Digital Frontier: Unraveling the Impact of Bank Technology Innovations on Idiosyncratic and Systemic Risks

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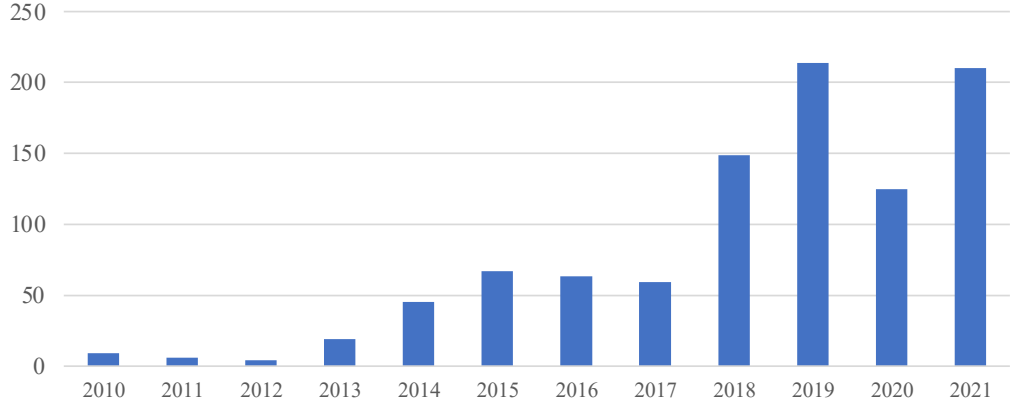
Research questions

What is the nature, scale and source of Fintech solutions adopted at banks?

What is the impact of technological development on discovering different sources of risks in the banking sector.

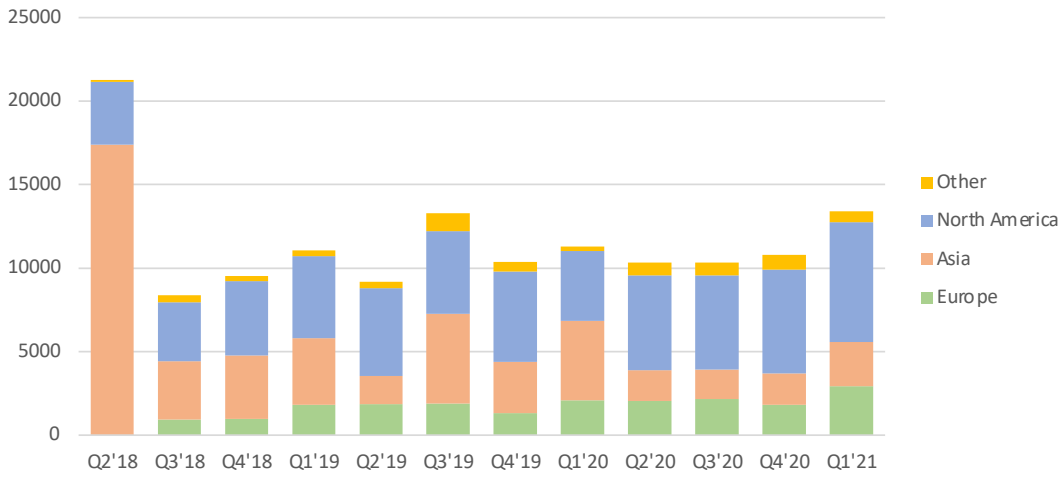
Global technology spending is expected to exceed USD 4 trillion in 2023

Global Fintech investment between 2010 and 2021 (in bln USD)



Source: Statista

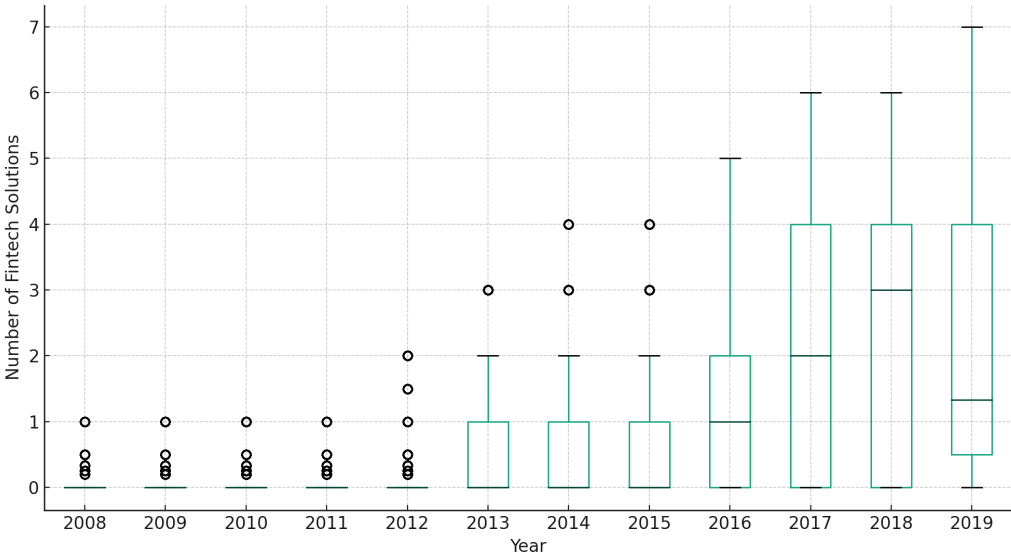
Global Fintech investment by regions (in bln USD)



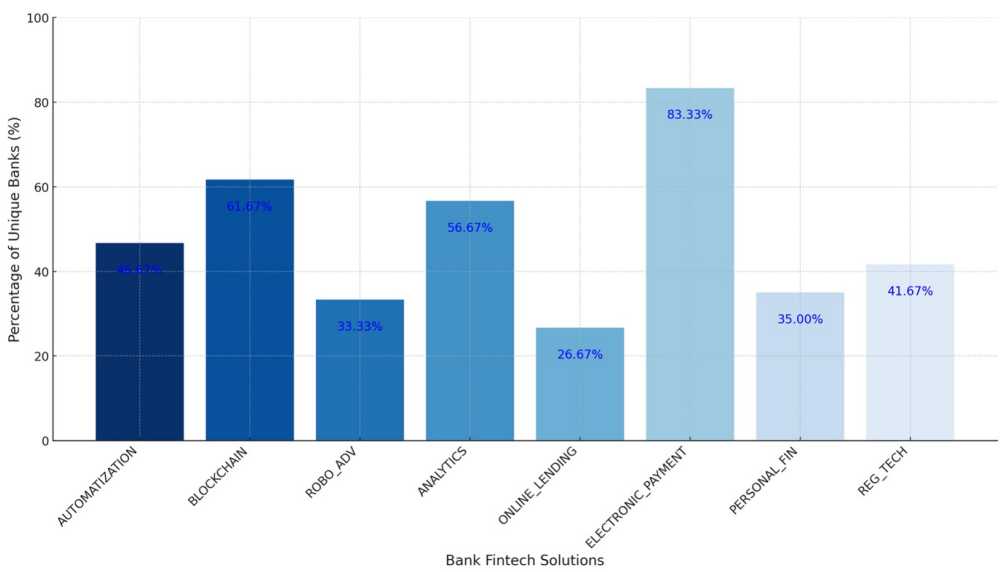
Source: CBInsights

The banking sector is the largest beneficiary of technological development, though differences between the banks and countries are significant.

Bank technological development over the years



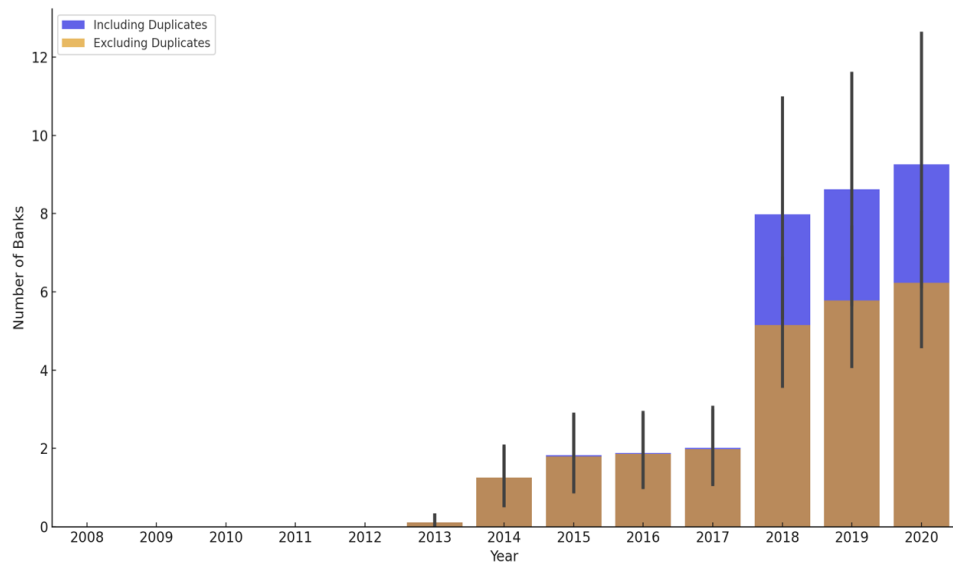
Percentage usage of bank fintech solutions



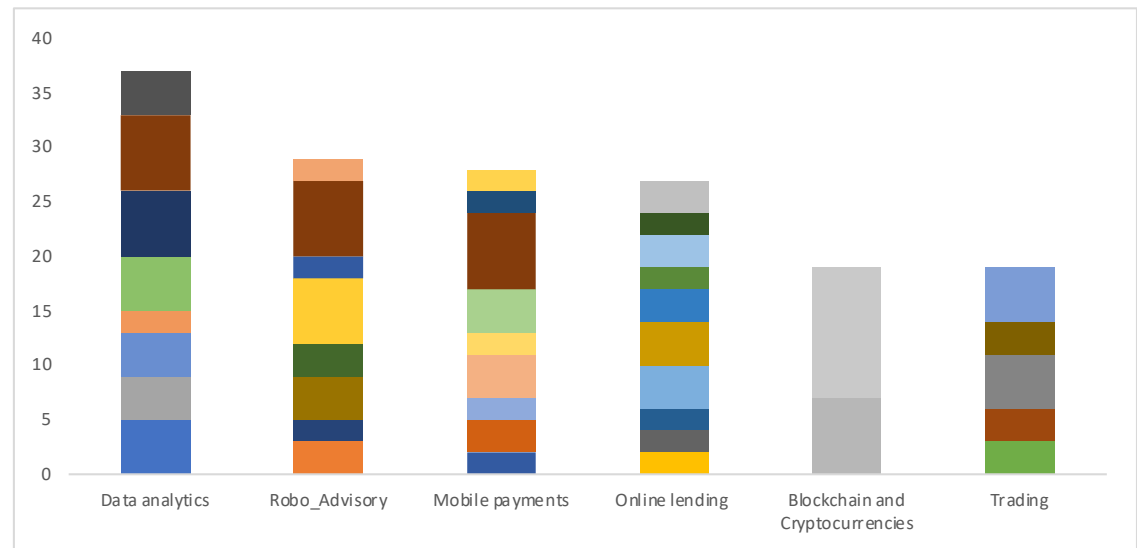
Source: own elaboration

Concentration of technology providers in the banking sector

Scale of banks using the same technology providers over time



Scale of banks using the same technology providers over time



Source: Own elaboration

Literature Review



The nature of operating of the Fintech sector:

- study of Fintech innovation by Chen et al. (2019)
- study by Lerner et al. (2021)

Digitalization in the banking sector:

- bank regulatory efficiency (Philippon, 2015)
- faster loan-decision processing (Fuster et al., 2019; Beaumont et al., 2022)
- increased access to financial services (Jagtiani & Lemieux, 2018; Huang et al., 2021; Hryckiewicz et al., 2022)
- credit supply (Branzoli et al., 2021; Kwan et al., 2021)
- credit risk assessment (Bazarbash, 2019; Berg i in., 2020; Gambacorta i in., 2020; Ouyang, 2022)
- impact on banks' NPLs (Pierri and Timmer, 2022) before the GFC and afterword

Literature Review



Algorithmic-decision making:

- impact on systemic events in the stock market by Jain et al. (2016); Malceniiece et al. (2019) or Paulin et al. (2019)
- bias in decisions (Sweeney (2013), Ensign et al. (2017), and Lambrecht and Tucker (2019)

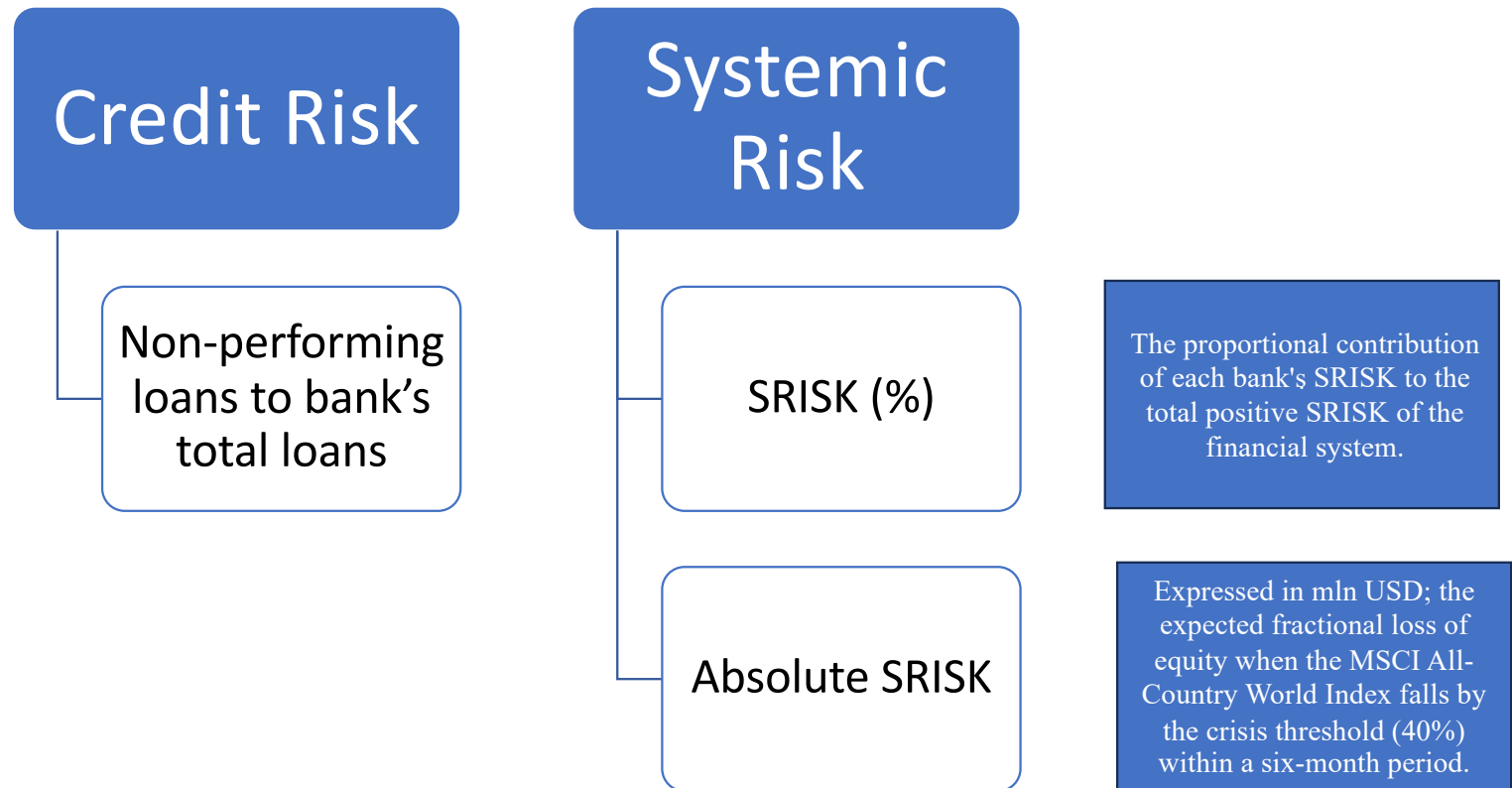
Sample

- We analyze the technological adoption by **63 largest European and US banks over the period of 2008 and 2019** which we then extend to 363 banks.
- We use **the data mining techniques** to identify the typology of technological solutions adopted by each bank over the sample period.
- To measure banks' digitalization we use the **typology of technology adoption**: (AUT.SOFT), blockchain technology (BLOCKCHAIN), data analytics (ANALYTICS), lending solutions (LENDING), payments (PAYMENTS), personal finance (PERSON.FIN), and regulatory technology (REGULAT).
- **In the robustness**, we also use the **ratio of intangible asset to bank's total asset** as an alternative measure for bank technological development.
- We also create an **innovation dummy**, the sum of all solutions a bank adopts in a given year.
- We also control for the **source of bank's technology adoption**: investment, outsourcing and partnership with Fintech and **concentration of the technology providers** within the banking sector.

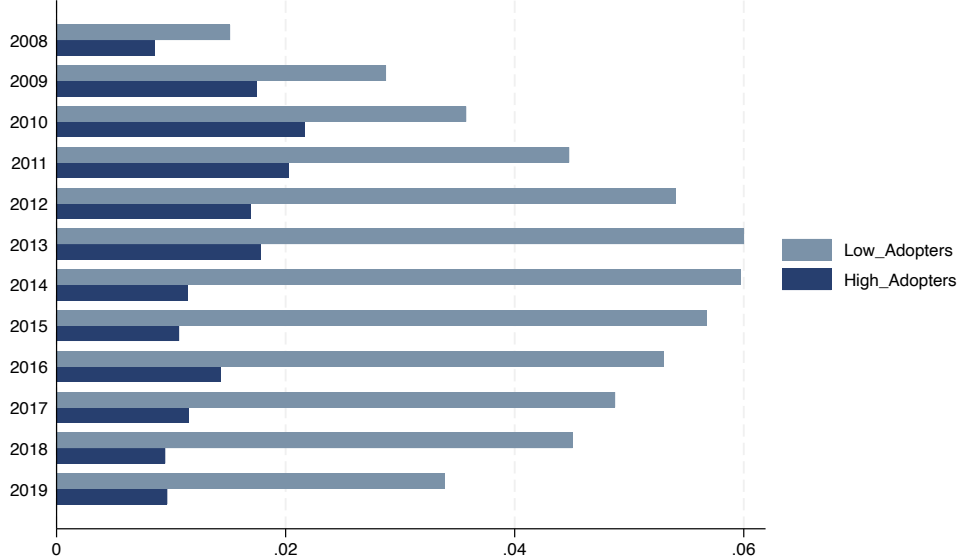
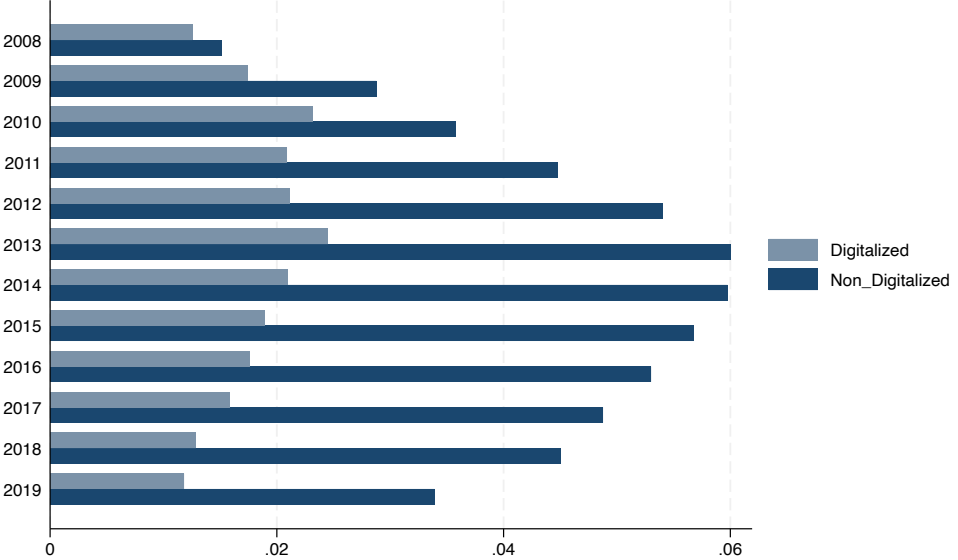
Methodology (part I)

- To identify the role of technology on banks' NPLs share we use the **Difference-in-Difference (DID)** approach where the treatment starts in 2011 (the first year after the financial crisis). Moreover, the **banks enter the treatment group if the number of solutions has increased the median number of all solutions for the entire sample**, i.e., when it is higher than 4 (**high versus zero**).
- We compare the treatment banks (*HighAdopters*) to banks with lower number of technological solutions (*LowAdopters*) or no adopted solutions (**control group**).
- The presence of systematic differences between the treatment and control groups in the sample is not an issue because the DID methodology does not rely on random assignment to treatment (Angrist and Pischke, 2009; Cameron and Trivedi, 2005). Indeed, **the identifying assumption is that the two groups follow the same trend in absence of treatment**. This is likely to happen in our setting because: **(i)** we include country and year-fixed effects, which are not included in a standard DID approach, **(ii)** the treatment and control groups are not fixed over time, i.e., at a given point an untreated bank enters in the treatment group when it is subject to a sharp increase in the digitalization; **(iii)** all banks experienced the same shock between 2008 and 2010.

Methodology (part II): Measures of risk



Average distribution of banks' NPLs between different groups



We start with the normal regression with interaction term to test the break in the digitalization data

	(1) NPL_Ratio	(2) NPL_Ratio	(3) NPL_Ratio	(4) NPL_Ratio
L. TECH_DEV	-0.00282 (0.00258)	-0.000680 (0.00281)	-0.000762 (0.00244)	0.00234 (0.00240)
TECH_DEV *Year2009		-0.00233 (0.00318)		
TECH_DEV *Year2010			-0.00186 (0.00148)	
TECH_DEV *Year2011				-0.00390** (0.00168)
Observations	445	445	445	445
R-squared	0.276	0.276	0.277	0.283
Time Varying Bank Controls	YES	YES	YES	YES
Time Varying Country Controls	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES

Static DID regression: NPLs ratio

	(1)	(2)	(3)	(4)
	NPL_share	NPL_share	NPL_share	NPL_share
Interaction	-0.0239**	-0.0223**	-0.0232**	-0.0199***
	(0.0107)	(0.0110)	(0.00907)	(0.00615)
Observations	537	537	436	417
Number of bvdencode	55	55	55	55
R-squared	0.067	0.108	0.221	0.374
Bank FE	YES	YES	YES	YES
Time FE		YES	YES	YES
Time Varying Macroeconomic Controls			YES	YES
Time Varying Bank Controls				YES

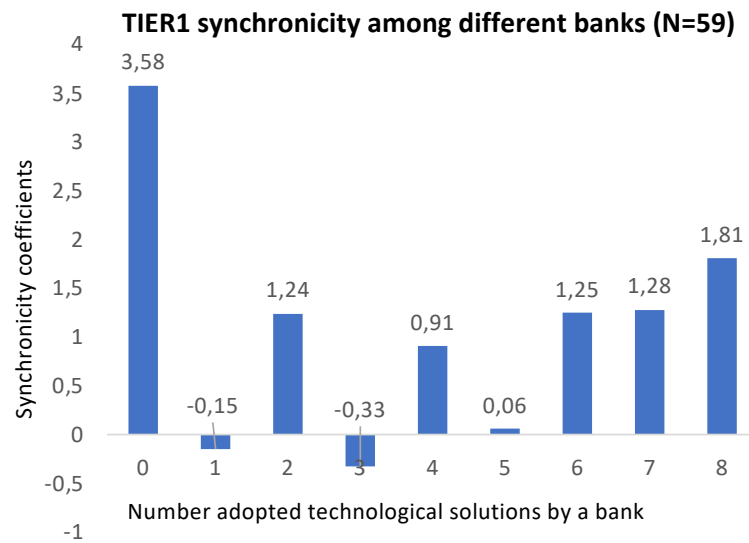
Dynamic DID regression: NPLs ratio

	(1) NPL_share	(2) NPL_share	(3) NPL_share	(4) NPL_share
YearDummy2009*treated banks	-0.00557** (0.00225)	-0.00560** (0.00225)	0.000180 (0.0104)	-0.00943 (0.00932)
YearDummy2010 *treated banks	-0.0080 (0.0053)	-0.0082 (0.0052)	-0.0026 (0.0108)	-0.0073 (0.0051)
YearDummy2011 *treated banks	-0.0187** (0.00737)	-0.0187** (0.00740)	-0.0236** (0.00935)	-0.0236** (0.00960)
YearDummy2012*treated banks	-0.0292*** (0.0100)	-0.0291*** (0.0100)	-0.0370*** (0.0104)	-0.0338*** (0.0113)
YearDummy2013*treated banks	-0.0348*** (0.0129)	-0.0348*** (0.0129)	-0.0335*** (0.0110)	-0.0234* (0.0138)
YearDummy2014*treated banks	-0.0366*** (0.0132)	-0.0363*** (0.0132)	-0.0334*** (0.00945)	-0.0279** (0.0125)
YearDummy2015*treated banks	-0.0337** (0.0147)	-0.0333** (0.0148)	-0.0357*** (0.0102)	-0.0271*** (0.00950)
YearDummy2016*treated banks	-0.0302* (0.0157)	-0.0302* (0.0158)	-0.0306*** (0.0105)	-0.0264** (0.0116)
YearDummy2017*treated banks	-0.0266* (0.0156)	-0.0263 (0.0157)	-0.0339** (0.0153)	-0.0350** (0.0157)
YearDummy2019*treated banks	-0.0143 (0.0110)	-0.0141 (0.0111)	-0.0574** (0.0281)	-0.0640** (0.0299)
Observations	537	537	436	417
R-squared		0.112	0.253	0.378
Number of banks	55	55	55	55
Bank FE	YES	YES	YES	YES
Time FE		YES	YES	YES
Time Varying Macroeconomic Controls		YES	YES	YES
Time Varying Bank Controls		YES	YES	YES

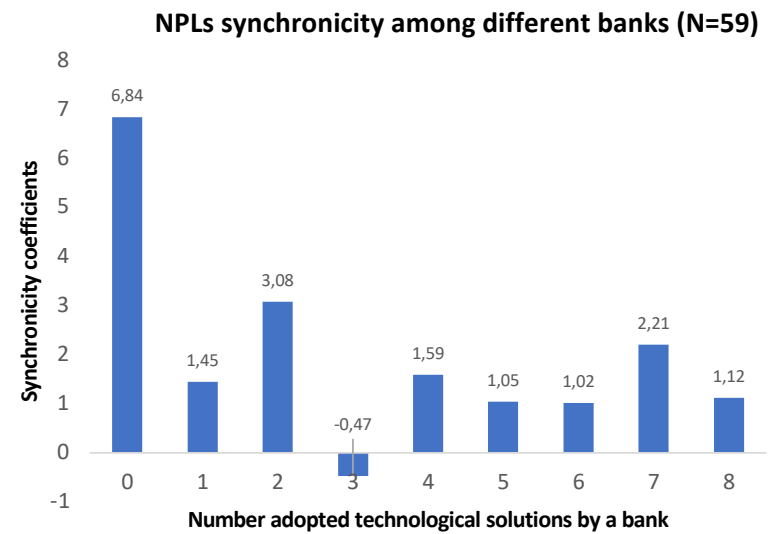
Systemic Risk Examination - Synchronicity Analysis

- To analyze the systemic risk between banks we start with the **synchronicity regressions** to analyze the correlation between different risk indicators (**NPLs share, TIER1 capital level**) in the banking sector as well as a correlation between the algorithmic decisions **embedded in the technological solutions** adopted by banks. The idea of the synchronicity analysis can be found by Chan et al. (2013).
- To analyze the **impact of digitalization on the systemic banking sector** we use the dynamic fixed-effect estimator (**both bank-and time fixed effects**), adding also other bank and country control variables as one-period lags to avoid the simultaneous bias.
- We use the **SRISK** measures in **absolute terms SRISK** and **relative terms (%SRISK)** to measure the systemic risk. The measure shows banks' capital shortage when the stock market index drops by 40% in a six-month period. The index (Acharya et al., 2012; Acharya et al., 2017; Brownlees and Engle, 2017; Engle et al., 2012).

Synchronicity regressions



Lower co-movement of TIER1 among the technologically advanced banks, as compared to no solution banks.



Lower co-movement of NPLs among the technologically advanced banks, as compared to no solution banks.

Impact of technological solutions on systemic risk measures

	SRISK%	SRISK
TECH_DEV	-0.185** (0.074)	-3.0e+03*** (687.146)
L1.SIZE	0.725** (0.330)	2.5e+04*** (3063.665)
L1. EQUITY RATIO	-0.136** (0.064)	-1.5e+03** (593.073)
L1.LOAN ACTIVITY	-0.013 (0.012)	66.270 (111.293)
L1.NON_INTEREST	-0.005 (0.007)	-53.520 (62.074)
L1.DEPOSIT RATIO	0.004 (0.006)	17.070 (53.517)
L1.NPL_SHARE	0.008 (0.025)	639.514*** (229.486)
L1. ROA	-0.140 (0.165)	-492.933 (1531.313)
GDP	0.008 (0.045)	597.517 (414.323)
INFLATION	-0.046 (0.087)	-1.3e+03 (807.036)
Observations	491	491
R-squared	0.874	0.900
Bank FE	Yes	Yes
Time FE	Yes	Yes

Impact of technology providers' concentration on systemic risk

	SRISK%	SRISK%	SRISK	SRISK
TECH_DEV	-0.111 (0.075)	-0.108** (0.054)	-2.2e+03*** (698.178)	-392.676 (505.509)
SHARING	0.002 (0.002)		46.121*** (17.539)	
Observations	491	491	491	491
R-squared	0.891	0.892	0.912	0.911
Bank controls	YES	YES	YES	YES
Macro controls	YES	YES	YES	YES
BANK FE	YES	YES	YES	YES
TIME FE	YES	YES	YES	YES

Robustness:

Using Intangible asset ratio at the 75 quantile variable distribution as an alternative for HighAdopters

	(1)	(2)	(3)	(4)
	NPL_share	NPL_share	NPL_share	NPL_share
YearDummy2009*treated banks	-0.00169 (0.00340)	-0.00196 (0.00345)	0.000843 (0.00376)	-0.00363 (0.00641)
YearDummy2010*treated banks	-0.00718 (0.00507)	-0.00712 (0.00512)	-0.00415 (0.00535)	-0.00732 (0.00618)
YearDummy2011*treated banks	-0.0201*** (0.00774)	-0.0203** (0.00780)	-0.0176** (0.00830)	-0.0152** (0.00669)
YearDummy2012*treated banks	-0.0297*** (0.00911)	-0.0302*** (0.00916)	-0.0287*** (0.00882)	-0.0307*** (0.0111)
YearDummy2013*treated banks	-0.0324*** (0.0125)	-0.0327** (0.0125)	-0.0302** (0.0125)	-0.0172** (0.00754)
YearDummy2014*treated banks	-0.0288*** (0.0105)	-0.0293*** (0.0106)	-0.0268** (0.0101)	-0.0161** (0.00716)
YearDummy2015*treated banks	-0.0253** (0.0107)	-0.0258** (0.0108)	-0.0238** (0.0102)	-0.0134* (0.00680)
YearDummy2016*treated banks	-0.0251** (0.0109)	-0.0256** (0.0109)	-0.0257** (0.0111)	-0.0186** (0.00825)
YearDummy2017*treated banks	-0.0194*** (0.00621)	-0.0204*** (0.00657)	-0.0171*** (0.00638)	-0.0161** (0.00708)
YearDummy2019*treated banks	-0.0205*** (0.00735)	-0.0214*** (0.00769)	-0.0363*** (0.0117)	-0.0457*** (0.0139)
Observations	604	604	501	476
R-squared	0.04	0.167	0.213	0.464
Number of banks	58	58	57	57
Time FE	YES	YES	YES	YES
Bank FE		YES	YES	YES
Time-Varying Macroeconomic Controls		YES	YES	YES
Time-Varying Bank Controls		YES	YES	YES

Robustness:

Using Intangible asset ratio at the 75 quantile variable distribution as an alternative for HighAdopters

	(1)	(2)	(3)	(4)
	NPL_share	NPL_share	NPL_share	NPL_share
YearDummy2009*treated banks	-0.00169 (0.00340)	-0.00196 (0.00345)	0.000843 (0.00376)	-0.00363 (0.00641)
YearDummy2010*treated banks	-0.00718 (0.00507)	-0.00712 (0.00512)	-0.00415 (0.00535)	-0.00732 (0.00618)
YearDummy2011*treated banks	-0.0201*** (0.00774)	-0.0203** (0.00780)	-0.0176** (0.00830)	-0.0152** (0.00669)
YearDummy2012*treated banks	-0.0297*** (0.00911)	-0.0302*** (0.00916)	-0.0287*** (0.00882)	-0.0307*** (0.0111)
YearDummy2013*treated banks	-0.0324*** (0.0125)	-0.0327** (0.0125)	-0.0302** (0.0125)	-0.0172** (0.00754)
YearDummy2014*treated banks	-0.0288*** (0.0105)	-0.0293*** (0.0106)	-0.0268** (0.0101)	-0.0161** (0.00716)
YearDummy2015*treated banks	-0.0253** (0.0107)	-0.0258** (0.0108)	-0.0238** (0.0102)	-0.0134* (0.00680)
YearDummy2016* treated banks	-0.0251** (0.0109)	-0.0256** (0.0109)	-0.0257** (0.0111)	-0.0186** (0.00825)
YearDummy2017* treated banks	-0.0194*** (0.00621)	-0.0204*** (0.00657)	-0.0171*** (0.00638)	-0.0161** (0.00708)
YearDummy2019* treated banks	-0.0205*** (0.00735)	-0.0214*** (0.00769)	-0.0363*** (0.0117)	-0.0457*** (0.0139)
Observations	604	604	501	476
R-squared	0.04	0.167	0.213	0.464
Number of banks	58	58	57	57
Time FE	YES	YES	YES	YES
Bank FE		YES	YES	YES
Time-Varying Macroeconomic Controls		YES	YES	YES
Time-Varying Bank Controls		YES	YES	YES

Robustness: Instrumental Variable Regression

VARIABLES	(1)	(2)	(3)	(4)	(5)
	NPL_ratio	NPL_ratio	NPL_ratio	NPL_ratio	NPL_ratio
	TECH_DEV	IT_EXPENS E	INTANGIBLE_ASS ET	INTANGIBLE_ASS ET	INTANGIBLE_ASS ET
Instruments	Bank Branch	Bank Branch	Fintech Credit	Number of grants	Number of fillings
TECH_DEV	-0.045*** (0.016)	-0.003* (0.002)	-0.081** (0.035)	-12.00*** (1.308)	-14.47*** (3.307)
SIZE	-0.023 (0.014)	-0.036** (0.016)	-0.039*** (0.013)	0.131*** (0.015)	0.154*** (0.034)
EFFICIENCY	0.0002*** (0.000)	0.000 (0.0001)	0.000 (0.000)	-0.080*** (0.022)	-0.102*** (0.038)
LOAN_ACTIVITY	0.0001 (0.0004)	-0.002** (0.001)	0.0002 (0.0003)	0.108*** (0.030)	0.135*** (0.048)
EQUITY_RATIO	0.001 (0.001)	0.002* (0.001)	0.0003 (0.001)	0.437*** (0.063)	0.414*** (0.080)
ROA	-0.004 (0.003)	(0.002) -0.006	-0.006*** (0.002)	-4.502*** (0.601)	-5.357*** (1.227)
GDP GROWTH	0.001 (0.001)	-0.002 (0.004)	0.0008 (0.002)	-0.683*** (0.082)	-0.736*** (0.105)
INFLATION	-0.004 (0.004)	-0.015** (0.007)	0.001 (0.002)	0.161 (0.228)	0.131 (0.265)
BANK CONCENTRATION	0.002*** (0.001)	0.001** (0.001)	-0.0001 (0.0002)	0.0004* (0.0002)	0.00059* (0.0003)
Observations	476	292	280	618	618
R-squared	-0.006	0.044	0.346	-0.333	-0.876
Bank FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES
Hansen J-Statistic (well- identified)	0.000	0.000	0.000	0.000	0.000
Kleinberger-Paap W- (weak identification)	24.241	6.680	7.765	4.345	6.545

Conclusions

- Banks mainly rely on back-office solutions which improve banks access to data and information processing.
- We find that banks with more Fintech solutions tend to have lower levels of NPLs and that this effect increases with time and the number of adopted solutions.
- We also found that Fintech solutions in the banking sector decrease systemic risk, with mobile payment solutions having the most significant impact.
- Reliance on external providers increase global risk if banks share the same technology.
- These results are robust to different technological measures, sample selection, and systemic risk indicators.